VAN NOSTRAND'S
ECLECTIC
ENGINEERING MAGAZINE.

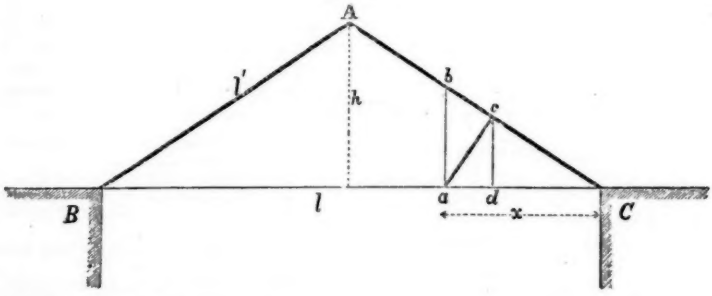
NO. XXIX.—MAY, 1871.—VOL. IV.

ROOF TRUSSES OR TRUSSED TRIANGLES.

BY S. H. SHREVE, CIVIL ENGINEER.

Trussed triangles are in common use for roofs, and may be used in many cases to advantage for bridges. They present many interesting features in the consideration of the strains affecting them from permanent and from movable loads.

FIG. 1.



Let A B and B C represent two rafters whose thrust at their supports is taken by the main tie rod B C, and which are connected with the tie rod by bracing.

Let w = weight borne by this pair of rafters.
l = distance between the walls B and C.
l' = length of one rafter.
h = height of centre of the rafters at the apex above the walls.
x = horizontal distance from one of the walls.

Disregarding for the present the braces, and taking moments around a, distant x from the right abutment, that part of the roof to the right of a is kept in equilibrium by the reaction of the right abutment, $= \frac{w}{2}$, the load on the rafter to the right of $a = \frac{w\,x}{l}$, and the longitudinal strain at b.

Hence L, the longitudinal strain, compression at b, multiplied by $a\,c$, distance from a at right angles to its direction, is equal to

$$\frac{w}{2} \times x - \frac{w\,x}{l} \times \frac{x}{2},$$

or,
$$L \times (a\,b) = \frac{w\,x}{2} - \frac{w\,x^2}{2\,l}.$$

From similar triangles,

$$l' : h :: x : a\,b, \text{ or } a\,b = \frac{h\,x}{l'}.$$

Substituting this value for $a\,b$, we have

$$L\frac{h\,x}{l'}=\frac{w\,x}{2}-\frac{w\,x^2}{2\,l}, \text{ and } L=\frac{w\,l'}{2\,h}-\frac{w\,x\,l'}{2\,h\,l}\ (1.)$$

When $x=0$, $L=\frac{w\,l'}{2\,h}$, the longitudinal strain at the abutment, and as $l' : h :: L : V$, the vertical strain at the abutment, which it will be seen is $\frac{w}{2}$, or the rafter bears upon the wall with the whole vertical strain.

In equation (1) L increases as x decreases, and is greatest at the abutment and least at the ridge; at the latter place $x=\frac{l}{2}$ and

$$L=\frac{w\,l'}{2\,h}-\frac{w\,l'}{4\,h}=\frac{w\,l'}{4\,h},$$

again,

$$l : \frac{l}{2} : : \frac{w\,l'}{4\,h} : \frac{w\,l}{8\,h}=H,$$

the horizontal strain.

In the same manner, taking moments around b, we have the horizontal strain in the main tie, which is tension.

$$H\times a\,b=\frac{w\,x}{2}-\frac{w\,x^2}{2\,l},$$

and

$$\frac{l}{2} : h : : x : \frac{2\,h\,x}{l}=\text{distance } a\,b,$$

substituting

$$H\,\frac{2\,h\,x}{l}=\frac{w\,x}{2}-\frac{w\,x^2}{2\,l}, \text{ or } H=\frac{w\,l}{4\,h}-\frac{w\,x}{4\,h}\ .\ .\ (2.)$$

Equation (2) is greatest when $x=0$, or at the abutment, where it is $\frac{w\,l}{4\,h}$, counteracting the horizontal component of the strain in the rafter at the same place; when

$$x=\frac{l}{2},\ H=\frac{w\,l}{8\,h},$$

H being the horizontal strain at a,

$$H'=\frac{w\,l}{4\,h}-\frac{w\,x'}{4\,h},$$

will be the horizontal strain at a point d, distant x' from c. The strain at d is greater than the strain at a; subtracting

$$H-H'=\frac{w\,x'}{4\,h}-\frac{w\,x}{4\,h},$$

is the difference in the horizontal strains at a and d. This difference could be caused by a tie from d to b, which would add to the tension at d; or a strut from a to c which would neutralize a certain amount of tension at a. Let there be a strut from a to c. If $\frac{w\,x'}{4\,h}-\frac{w\,x}{4\,h}$ be the horizontal component of its strain, then this component will be to the vertical component as $a\,d$ is to $d\,c$.

Or

$$x'-x : \frac{2\,h\,x'}{l} : : \frac{w}{4\,h}(x'-x) : \frac{w\,x'}{2\,l},$$

the vertical component of the strain in $a\,c$.

Now consider the roof braced as in Fig. 2, it is evident that $\frac{w\,x'}{2\,l}$ is the vertical strain in any brace whose upper end is distant x' from the abutment, and that this strain increases directly as x' increases, or the vertical strain or shearing strain in the web of a triangular truss increases from the abutment to the centre. This vertical strain is the full amount of the strain in the tie from the foot of the strut to the rafter.

We have now sufficient formulæ to determine all the strains affecting a roof truss of the form shown in Fig. 2.

The weight is considered as concentrated at the points where the braces meet the rafters, and the different members of the truss are subject to longitudinal strains only.

Let A F, F L represent a pair of rafters resting on the walls at A and L; A L the main tie rod receiving the whole thrust of the rafters; the vertical braces, ties; and the inclined braces, struts.

Let w = 50 tons, whole weight, uniformly distributed.
l = 100 feet, the distance A L.
l' = 51.4 feet the length of either rafter.
h = 12 5 feet, the height of the truss at the centre, F E.
x = distances from L the wall, to the points i, h, g, f, etc.
H, L, and V, represent horizontal, longitudinal and vertical strains.

The distances between the ends of the braces on the main tie rod are equal to each other, except the parts A b and h L, which are 20 ft. in length, the others being 10 ft. each.

Equation (1) is necessary to obtain strains in the main tie rod A L, substituting,

$$H=\frac{w\,l}{4\,h}-\frac{w\,x}{4\,h}=\frac{50\times 100}{4\times 12.5}-\frac{50\,x}{4\times 12.5}=100-x.$$

The first value of x is 10, whence

$$H=90 \text{ tons},$$

the horizontal tension at i, and as the tie receives no increase nor decrease be-

tween h and L, it is the strain in h L and correspondingly in A b.

When $x = 20$,

$$H = 80 \text{ tons},$$

tension at h; and as to the left of h there is but one member subject to a horizontal strain, it gives the total strain in that member, $h\,g$, and likewise $b\,c$.

In the same manner,

Tension in $g\,f$ and $c\,d = 70$ tons.
Tension in $f\,e$ and $d\,e = 60$ tons.

Equation (2) gives the strains in the rafters; substituting,

$$L = \frac{w\,l'}{2\,h} - \frac{w\,l'\,x}{2\,h\,l} = \frac{50 \times 51.42}{2 \times 12.5} - \frac{50 \times 51.42\,x}{2 \times 12.5 \times 100} = 102.84 - 1.028\,x.$$

When $x = 10$, L $= 92.56$ tons, compression in K L and A B.
" $x = 20$, L $= 82.27$ tons, compression in I K and B C.
" $x = 30$, L $= 71.99$ tons, compression in H I and C D.
" $x = 40$, L $= 61.70$ tons, compression in G H and D E.
" $x = 50$, L $= 51.49$ tons, compression in F G and E F.

The vertical equation $\frac{w\,x}{2\,l}$ will give the vertical component of the compression in the inclined struts. In any strut I g, for example, as the vertical distance I h is to the length of the strut I g, so is the vertical component of the strain to the whole strain in the strut, hence from $\frac{w\,x}{2\,l}$ and this proportion,

Compression in K h and B $b = 10.31$ tons.
Compression in I g and C $c = 11.18$ "
Compression in H f and D $d = 12.5$ "
Compression in G e and E $e = 14.14$ "

The vertical strain in any rod is $\frac{w\,x}{2\,l}$, x being the horizontal distance from the abutment to the upper end of the strut from the lower end of which the tie rises.

$$V = \frac{w\,x}{2\,l} = \frac{50\,x}{200}, = \frac{x}{4},$$

When $x = 10$, V $= 2.5$ tons, tension in I h and C b.
" $x = 20$, V $= 5.$ tons, tension in H g and D c.
" $x = 30$, V $= 7.5$ tons, tension in G f and E d.
" $x = 40$, V $= 10$ tons;

but as the vertical strain comes from the two struts G e and E e, F e receives a double strain, and its tension is 20 tons.

This added to the 5 tons directly on E, makes 25 tons supported by the apex.

FIG. 2.

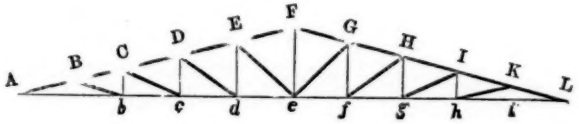


FIG. 3.

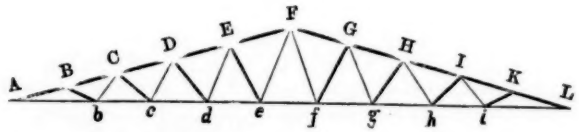


Fig. 3 is a form of roof truss also in common use, where the ties are inclined as well as the struts.

Let w, l, l', h, x, etc., have the same values and meaning as in Fig. 2, each rafter being divided into five equal parts by the braces, and in the main tie rod A b and l L are each 15 ft., and the distance between the other points is 10 ft.

The horizontal tension is found from equation (1), as before.

Tension in i L and A $b = 90$ tons.
" $h\,i$ and $b\,c = 80$ "
" $g\,h$ and $c\,d = 70$ "
" $f\,g$ and $d\,e = 60$ "
" $e\,f$ $= 50$ "

But equation (2) does not apply without some change. The first value of x in this case is 5, and though $\frac{w\,x}{2}$ is the moment of the reaction of the abutment, $\frac{w\,x^2}{2\,l}$ is not the moment of the load on x.

Let p = half the horizontal distance from K to L, the moment of that part of the weight resting directly on the wall is $\frac{w\,p\,x}{l}$, the balance of the weight on x is $\frac{w}{l}(x-p)$; we therefore obtain

$$L\frac{h\,x}{l'} = \frac{w\,x}{2} - \left(\frac{w\,p\,x}{l} + w\frac{(x-p)}{l}(x-p)\right) = \frac{w\,x}{2} - \frac{w\,x^2}{2\,l} + \frac{w\,p^2}{2\,l},$$

$$\therefore L = \frac{w\,l'}{2\,h} - \left(\frac{w\,x\,l'}{2\,h\,l} + \frac{w\,p^2\,l'}{2\,h\,l\,x}\right),$$

Substituting constants,

$$L = 102.84 - \left(1.028\,x + \frac{25\,7}{x}\right)$$

When $x =$ 5, L = 92 56 tons, compression in K L and A B.
" $x = 15$, L = 85.71 tons, compression in I K and B C.
" $x = 25$, L = 76.11 tons, compression in H I and C D.
" $x = 35$, L = 66.13 tons, compression in G H and D E.
" $x = 45$, L = 56.01 tons, compression in F G and E F.

The vertical strain as before is $\frac{w\,x}{2\,l}$, x being the distance from the abutment to the upper end of any strut; the tie next the strut towards the centre having the same vertical strain as the strut. The longitudinal strain can be found from its vertical component by the proportion given in the previous example. Hence we obtain

5.59 tons, compression in K *i* and B *b*.]
3.53 tons, tension in I *i* and C *b*.
7.07 tons, compression in I *h* and C *c*.
6.00 tons, tension in H *h* and D *c*.
9.01 tons, compression in H *g* and D *d*.
8.39 tons, tension in G *g* and E *d*.
11.18 tons, compression in G *f* and E *e*.
10.76 tons, tension in F *f* and F *e*.

Let Fig. 2 be inverted to be used as a bridge. The members all change the character of their strains, though the amount of strain to which each is subject remains the same. The truss is now subject to the action of variable as well as constant loads, the effects of which it is necessary to examine in order to properly proportion the parts.

Let the truss be partially but more than half loaded; let the load extend from the left abutment to a point distant u from the right abutment; w the weight of a full load of uniform density with the partial load, H, L, l, l', h and x have the same meaning as in the previous cases.

By the principles of the lever, $\frac{w}{2\,l^2}(l-u)^2$ will be the vertical reaction of the right abutment. Taking moments around a point in the main suspension rod, distant x horizontally from the right abutment, x being less than u.

$$H\frac{2\,h\,x}{l} = \frac{w\,x}{2\,l^2}(l-u)^2, \text{ whence } H = \frac{w}{4\,h\,l}(l-u)^2, \quad (3.)$$

the horizontal compression in the main chord.

In this equation H is constant for the whole length of u. In the same manner for the tension in the main tie,

$$L\frac{h\,x}{l'} = \frac{w\,x}{2\,l^2}(l-u)^2 \therefore L = \frac{w\,l'}{2\,h\,l^2}(l-u)^2 \quad (4.)$$

also a constant, or the compression in the chord and the tension in the main tie are the same from the end of the partial load to the abutment. Consequently no strain comes upon the braces between the end of the load and the abutment when the partial load is more than a half load.

From a partial load equation (3.)

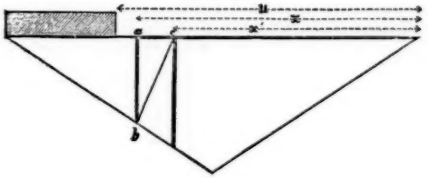
$$H = \frac{w}{4\,h\,l}(l-u)^2 = \frac{w\,l}{4\,h} - \frac{w\,u}{2\,h}\left(1 - \frac{x}{2\,l}\right),$$

as before stated, is the horizontal strain in the unloaded part. Under a full load the strain is $H = \frac{w\,l}{4\,h} - \frac{w\,x}{4\,h}$, decreasing as x increases, and is consequently least nearest the centre. Making $x = u$, we have $H = \frac{w\,l}{4\,h} - \frac{w\,u}{4\,h}$, showing plainly the strain from a full load is greater than the strain from a partial load. Similarly it may be shown that the longitudinal tension in the main tie is greatest under a full load.

The above equations (3) and (4) are true for any value of u only when x is less than $\frac{l}{2}$. That is, when the load covers less than half the truss, $H = \frac{w}{4\,h\,l}(l-u)^2$ is the horizontal strain in the chord, from the unloaded abutment to the centre; and $L = \frac{w\,l'}{2\,h\,l^2}(l-u)^2$ is the longitudinal strain in the main tie between the same points. But between the centre and the end of the load both strains change.

Let Fig. 4 represent a truss less than half loaded.

FIG. 4.



Let x again represent the distance from the right abutment to a point between the centre of the truss and the end of the load, and u the distance from the same abutment to the end of the load.

$$\frac{l}{2} : h :: l-x : \frac{2\,h\,(l-x)}{l}$$

is the vertical distance between the main tie and the chord at x, and

$$\therefore \text{H}\,\frac{2\,h\,(l-x)}{l} = \frac{w\,x^2}{2\,l^2}(l-u)^2; \text{ whence H} = \frac{w\,x\,(l-u)^2}{4\,h\,l\,(l-x)} \quad . \quad . \quad . \quad . \quad . \quad (5.)$$

is the horizontal strain from the reaction of the right abutment, in the chord at any point between the centre and the end of the load.

At the centre, where $x = \frac{l}{2}$, equation (5) becomes equal to equation (3), and thence to the end of the load the strain increases and is greatest when $x = u$, where $\text{H} = \frac{w\,u}{4\,h\,l}(l-u)$, a strain very evidently, by comparison with equation (1), less than the strain at the same point under a full load.

The decrease in the horizontal strain could not take place unless there were ties inclined as in a full load, that is, as in Fig. 4, or struts with the opposite inclination. The less than half load, therefore, requires the same braces as the full load.

Let $\text{H} = \frac{w\,x\,(l-u)^2}{4\,h\,l\,(l-x)}$ be the compression in the upper chord at a; and

$$\text{H}^1 = \frac{w\,x^1(l-u)^2}{4\,h\,l\,(l-x')},$$

the compression at c; then

$$\text{H}-\text{H}' = \frac{w\,(l-u)\,(x-x')}{4\,h\,(l-x)\,(l-x)}$$

is the horizontal component of the strain in $b\,c$, and this component is to the vertical component as $a\,c$ is to $a\,b$; or

$$x \quad x' : \frac{2\,h\,(l-x)}{l} :: \frac{w\,(l-u)^2\,(x-x')}{4\,h\,(l-x)\,(l-x')} : \frac{w\,(l-u)^2}{2\,l\,(l-x')} \quad (6.)$$

greatest when x' is greatest, which is when it equals u, in which case we have

$$\text{V} = \frac{w}{2\,l}(l-u) \quad . \quad . \quad . \quad . \quad (7.)$$

for the vertical strain in the bracing at the end of a less than half load.

The equation of the vertical strain under a full load at the same point is,

$$\text{V} = \frac{w\,x}{2\,l},$$

but in this case x is the distance from the left abutment or $l-u$; that is the vertical strain from the less than half load is equal to the vertical strain from the full load.

Again, $\frac{w\,(l-u)^2}{2\,l^2}$ the vertical reaction of the right abutment in the case supposed, is less than $\frac{w\,(l-u)}{2\,l}$; or the vertical strain at the end of the load, in the bracing, is greater than the vertical reaction of the right abutment.

It may be interesting to see what becomes of this excess of vertical strain between the end of the load and the centre.

In the same case and as H was determined,

$$\text{L} = \frac{w\,l'\,u}{2\,h\,l^2}(l-u),$$

the tension in the main tie rod under the end of the load,

$$l' : h :: \frac{w\,l'\,u}{2\,h\,l^2}(l-u) : \frac{w\,u}{2\,l^2}(l-u)$$

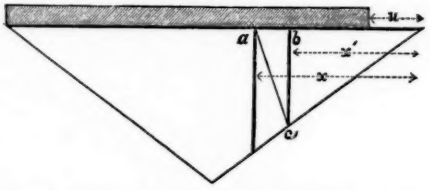
the vertical component of the longitudinal strain. This strain is passing towards the loaded end of the truss, or in the present example, towards the left abutment. Subtracting this from the vertical strain in the brace,

$$\frac{w}{2\,l}(l-u) - \frac{w\,u}{2\,l^2}(l-u) = \frac{w}{2\,l^2}(l-u)^2,$$

the reaction of the right abutment, or the excess of strain in the bracing is neutralized by an equal amount in the main tie rod.

It is next necessary to ascertain the bracing required under a partial load.

FIG. 5.



In Fig. 5, let u equal the length of the unloaded part, as before, and x the distance of any point under the load.

$$\therefore H\frac{2hx}{l} = \frac{wx}{2l^2}(l-u)^2 - \frac{w}{2l}(x-u)^2$$

and

$$H = \frac{w}{4hl}(l-u)^2 - \frac{w}{4hx}(x-u)^2 \quad . \quad (18.)$$

in which H increases as x decreases; this increase requires ties inclined as in a full load or as in Fig. 5. That is, as far as the centre, where H reaches its least value; beyond, H increases to the left abutn ent, requiring ties with the opposite inclination. At any other point b.

$$H' = \frac{w}{4hl}(l-u)^2 - \frac{w}{4hx'}(x'-u)^2$$

$$\therefore H-H' = \frac{w}{4hx'}(x'-u)^2 - \frac{w}{4hx}(x-u)^2 =$$

$$\frac{w}{4h}(x-x') - \frac{wu^2}{4h}\left(\frac{x-x'}{xx'}\right),$$

and as before,

$$x-x' : \frac{2hx'}{l} :: \frac{w}{4h}(x-x') - \frac{wu^2}{4h}\left(\frac{x-x'}{xx'}\right) : \frac{wx}{2l} - \frac{wu^2}{2lx}.$$

a strain passing in the same direction, but less by $\frac{wu^2}{2lx}$ than the vertical strain from a full load.

Hence we see that in every case the strains from the full load are the greatest, and that no braces are required for the partial load except those needed under a full load. So that equations (1) and (2) and the equation for the vertical strain are all that are needed to determine the strains and therefore make this one of the simplest forms of truss for calculation.

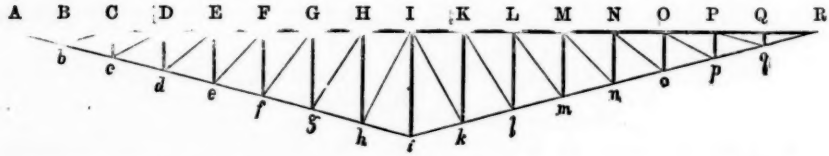
Let Fig. 6 represent a trussed triangle inverted for bridge purposes.

Let l = 200 feet, the length of the truss.
h = 20 feet, the depth at the centre.
l' = 103.1 feet, the length of the main ties.
w = 400000 lbs., the weight of the truss fully loaded.

The vertical braces are 12.5 ft. apart, horizontally.

As the strain upon each member is determined there is given with its weight, found from the valuable formulæ of Col. Merrill.

FIG. 6.



For the strains in the chord A R, compression, we have equation (2).

$$H = \frac{wl}{4h} - \frac{wx}{4h}.$$

Substituting the values given above,

$$H = \frac{400000\times200}{4\times25} - \frac{400000\,x}{4\times25} = 800000 - 4000\,x.$$

Making x the distance from the abutment to the end of each panel, we obtain

lbs.			Weight in lbs.
750,000	compression in	RQ, QP, AB and BC,	1,784 × 4 = 7,136
700,000	"	OP and CD	1,702 × 2 = 3,406
650,000	"	NO " DE.....	1,638 × 2 = 3,276
600,000	"	MN " EF	1,569 × 2 = 3,138
550,000	"	LM " FG.....	1,498 × 2 = 2,996
500,000	"	KL " GH.....	1,424 × 2 = 2,848
450,000	"	IK " HI	1,347 × 2 = 2,694
		Weight of cord.....	25,514

For the strains in the main ties we have equation (1.)

$$L = \frac{wl'}{2h} - \frac{wl'x}{2hl}$$

Substituting the values given above,

$$L = \frac{400000 \times 103.1}{2 \times 25} - \frac{400000 \times 103.1x}{2 \times 25 \times 200} = 824800 - 4124\,x.$$

Whence

773250 lbs.,	tension in	q R	and	A	b.
721700	"	"	"	$p\,q$	" $b\,c$.
670150	"	"	"	$o\,p$	" $c\,d$.
618600	"	"	"	$n\,o$	" $d\,e$.
567050	"	"	"	$m\,n$	" $e\,f$.
515500	"	"	"	$l\,m$	" $f\,g$.
463950	"	"	"	$k\,l$	" $g\,h$.
412400	"	"	"	$i\,k$	" $h\,i$.

The weight of which (two ties) by Merrill's formulæ is 34,074 lbs.

$V = \frac{w\,x}{2\,l}$, is the vertical strain or the vertical component of the longitudinal strain in any inclined brace, x being the distance. Substituting the values given above,

$$V = \frac{400000\,x}{2 \times 200} = 1000\,x.$$

Whence from the proportion of the vertical to the longitudinal, we obtain,

51,520 lbs.,	tension in	P q	and	b C,	weight	184	3×2=	368.6 lbs.
55,880	"	"	O p	" c D,	"	211.4	×2=	422.8 "
62,480	"	"	N o	" d E,	"	271.1	×2=	542.2 "
70,080	"	"	M n	" e F,	"	380.2	×2=	760.4 "
80,160	"	"	L m	" f G,	"	446.2	×2=	892.4 "
90,120	"	"	K l	" g H,	"	564	×2=1,128	"
100,762	"	"	I k	" h I,	"	705	×2=1,410	"

Total weight of tension braces .....5,524 4 lbs.

The vertical braces are subject to the vertical strain in the diagonals next towards the nearest abutment and that part of the whole weight which comes directly upon the verticals, which in this case is 25,000 lbs., whence,

Lbs.							Lbs.
25,000	compression on	Q q	and	B b,	weight	...	21×2= 42
37,500	"	" P p	"	C c,	"	...	98×2= 196
50,000	"	" O o	"	D d,	"	...	243×2= 486
62,500	"	" N n	"	E e,	"	...	471×2= 942
75,000	"	" M m	"	F f,	"	...	796×2=1,592
87,500	"	" L l	"	G g,	"	...1,223×2=2,446	
100,000	"	" K k	"	H h,	"	...1,804×2=3,608	
200,000	"	" I i				...	3,280

Weight of vertical braces.....12,592

For the purpose of comparison, we give the strains and the weight of a Fink truss, not only to show the greater lightness of the trussed triangle, but also because they resemble each other in having a single straight chord.

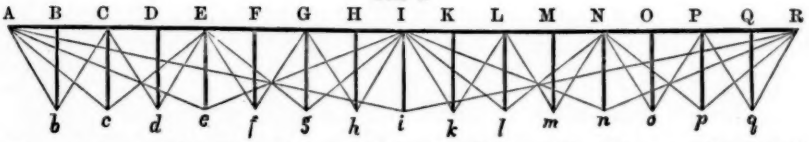
Let Fig. 7 represent a Fink truss 200 ft. in length, 18.75 ft. in depth and supporting a weight of 400,000 lbs.

The posts B b, D d, F f, H h, K k, M m, O o, and Q q, each bear the weight of one-sixteenth of the whole load, or 25,000 lbs.

The weight of each, 628 lbs.; of the eight, 5,024 lbs.

Compression on C c, G g, L l and P p= 50,000 lbs.

FIG. 7.



The weight of each, 883 lbs. × 4 = 3,332 lbs.

Compression on E e and N n = 100,000 lbs.

Weight 1,313 lbs. × 2 = 2,626 lbs.

Compression on I i, 200,000 lbs., weight, 1,898 lbs.

Total weight of the posts = 12,880 lbs.

The strain on any tie is easily determined from the strain in the post to which it is attached. The latter being one half the vertical component of the former. Therefore, as the length of the post is to the length of the tie, so is half the strain on the post to the strain on the tie. Whence we have

Tension on	16	ties	15,020 lbs.,	weight	94 × 16 =	1,504 lbs.
"	8	"	41,667 "	"	362 × 8 =	2,896 "
"	4	"	142,400 "	"	2,112 × 2 =	8,448 "
"	2	"	542,613 "	"	15,335 × 2 =	30,670 "

Weight of ties..... .. ..43,518 lbs.

The horizontal strain upon the chord is uniform throughout its length and is the horizontal components of the strains in each set of ties. Its amount is 708,333 lbs.

16 pieces, weight 1,718 lbs. × 16 = 27,488 lbs.

Total weight of one Fink Truss.

Chord	27,488 lbs.
Posts	12,880 "
Ties	43,518 "
Total	83,886 lbs.

Total weight of one Trussed Triangle.

Chord	25,514 lbs.
Posts	12,592 "
Diagonal ties	5,524 "
Main ties	34,074 "
Total	77,704

A simple trussed triangle weighing 77,704 lbs. will support 6,182 lbs. more than a Fink truss weighing 83,886 lb., or the former will support 322,296 lbs. while the full load of the latter will be 316,114 lbs. And not only will it be lighter, and stronger, but it will be far more economically constructed, in practice possess many advantages, and be far more creditable to the reputation of the engineer.

SOLAR HEAT—ITS INFLUENCE ON THE EARTH'S ROTARY VELOCITY.

(*Continued from page* 341.)

Respecting the African rivers, none of which have been entered in the Tables, it may be briefly stated that they have no material influence on the earth's rotation, from the fact that the two principal rivers, the Nile and the Niger, flow in opposite directions, the former towards the pole and the latter towards the equator. There is, however, considerable difference of latitude productive of an increased retarding influence of the Nile; but this cannot be far from balanced by the greater quantity of sedimentary matter brought down by the Niger, as proved by its delta of 240 miles of coast. The general course of the other important rivers of Africa, the Senegal, Zambesi, and the Orange river, is so nearly parallel with the equator, that they exercise no appreciable influence on the axial rotation of the earth.

Australia being drained by rivers, the courses of which are directed to all points of the compass, consequently exercising no appreciable influence as regards the earth's rotary motion, has likewise been excluded from the Tables. It should be observed, that the basin of the important river Goolwa and its tributaries (excepting the Callewatta) is almost on the same parallel with the mouth of the main river; hence scarcely any retarding force is produced, notwithstanding the great extent of basin drained by the Goolwa. The Amazon, which drains more than two millions of square miles, strikingly illustrates the influence on the earth's rotary velocity of rivers the centres of whose basins are nearly on the same parallel with their outlets, the enormous mass of solid matter carried to the ocean by this river, the greatest on the globe, exerting a retarding influence of only 70,000 foot-pounds per second.

The aggregate of solid matter removed from its original position by the river systems of both hemispheres, and carried towards the equator—consequently removed to a greater distance from the axis of rotation—exerts, as shown by the Tables, a retarding influence of 39,894,658 foot-pounds per second. If we multiply this amount by 86,400 seconds, we learn that for each revolution, the earth has to overcome a retarding energy represented by 3,446,898,451,200 foot-pounds; but the effect of this retardation as regards the length of the century cannot be properly considered until we have investigated the second class of force before adverted to, viz.: that force which destroys the earth's vis viva without disturbing the position of its centre of gyration. Want of space will prevent an examination of this second class of retarding force, on the present occasion; more especially as the counteracting influence of the sediment which is carried towards the poles demands consideration. We have, however, proceeded far enough with our demonstration to prove the fallacy of the accepted doctrine of compensation relative to the energies which affect the earth's rotary velocity. We have clearly shown that constancy of rotation of the earth is incompatible with solar influence.

NOTE.—I have to state, in reply to correspondents, that the weather was not favorable for observing the maximum intensity of solar radiation on the 1st day of January. On the 7th, however, the sky was so clear as to admit of very exact actinometer observations being made. Regarding the delay, it will be proper to observe, that the distance of the earth from the sun increases only $\frac{12}{100000}$ during the first seven days after passing the perihelion, a difference too small to influence the intensity of the sun's radiant heat in a degree sufficient to affect perceptibly the indication of the thermometer. The result of

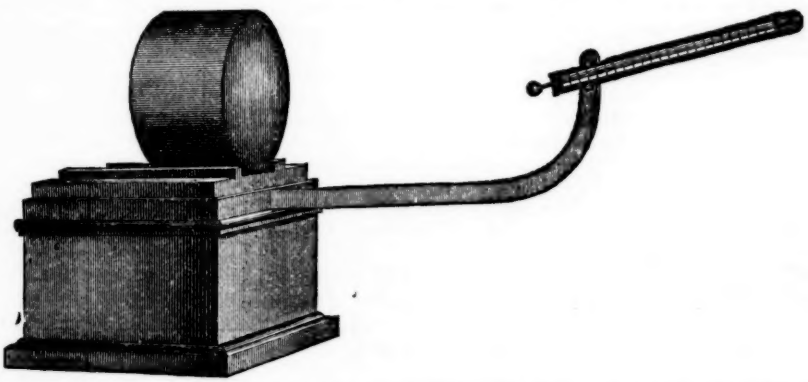
the observation of the 7th January referred to, may be thus briefly recorded: The greatest intensity 57. 25 deg. Fahr. was reached near noon, the sun's zenith distance being 63 deg. 15 min. By reference to the Table of maximum solar intensity, published in a previous article, it will be seen that for corresponding zenith distance—65 deg. 15 min.–the sun's radiant heat is 51.77 deg. when the earth passes the aphelion. Consequently, the increase of temperature at midwinter, established by the observations of the 7th January is 57.25 − 51.77 = 5.48 deg. Fahr. Agreeable to the theoretical deductions in the previous article alluded to, the maximum increase of temperature resulting from the approach of the earth toward the sun in winter. should be 5. 88 deg. The difference 0.4 deg. would no doubt have been less if the sun on the 7th had been perfectly clear. It will be safe, therefore, to assume that by means of the actinometer, we have ascertained the intensity of solar radiation with sufficient exactness for all practical purposes.

THE TEMPERATURE OF THE SUN.

By CAPTAIN JOHN ERICSSON.

From "Engineering."

The following illustration represents a perspective view of an apparatus constructed for the purpose of proving the correctness of the indications of my solar pyrometer, described in a previous article. Objections have, not unreasonably, been raised against this instrument on account of the low temperature em-



ployed. It is contended that unless the radiator is raised to the temperature of incandescence, emitting luminous rays, the radiant heat transmitted to the focus will not furnish a true indication for determining the temperature of distant incandescent bodies. Numerous experiments, however, show that, relatively, there is no appreciable difference between the energy of the dark heat rays emanating from a metallic radiator of low temperature, presenting a thoroughly disintegrated or a blackened surface, and the energy of heat rays accompanied by a light emanating from an incandescent metallic radiator. The temperature transmitted by the radiant heat to the focus is, in each case, directly proportional to the temperature of the radiant surface. Indeed, an air thermometer placed in the focus of a concave spherical radiator of ice, and surrounded with very cold substances, say 100 deg. below zero, will furnish an indication by which the temperature of distant incandescent bodies may be ascertained with as much certainty as by employing a radiator heated to such a degree as to emit luminous rays. It scarcely needs explanation that my reason for constructing the solar pyrometer with

a radiator kept at the low temperature of boiling water, is that of admitting of operating within a vacuum, besides rendering it possible to measure the temperatures with positive exactness. No doubt the instrument might be so arranged that the metallic radiator could be maintained at a temperature considerably above that of incandescence (Sir Humphrey Davy, it will be remembered, fixed the temperature of incandescence at 812 deg.); but we lack accurate means of measuring the intensity when metals are heated to such a degree that their color somewhat resembles that of the sun, viz., white heat, or light orange. Nor would anything be gained by resorting to a mode of construction involving both complication and uncertainty, since dark heat rays, with reference to temperature, in no manner differ from heat rays accompanied by light. No irregularity has been observed in the fall of the temperature of an incandescent radiator, and that of the focal thermometer exposed to the radiant heat, while the color gradually changes from light orange to black. On the contrary, the temperatures of the radiator, and the recipient of the radiant heat, continue to bear the same relation to each other during both cooling and heating. The times, compared with the increment or diminution of intensity, differ a little; but, as stated, the proportion between the temperature of the radiant surface and that transmitted to the focus, continues as nearly uniform as experimental test can determine.

The radiator of the instrument represented by our illustration, which may appropriately be termed testing apparatus, consists of a solid cylindrical block of cast iron 10 in. diameter, 6 in. long, placed horizontally on a pedestal, the front end forming a spherical concavity of 18 in. radius, precisely like the radiator of the solar pyrometer. The underside of the cylindrical block is provided with a square projection corresponding with two guide pieces on the top of the pedestal, to facilitate the placing the block rapidly in a proper position after having been heated in an air furnace. A focal thermometer, similar to the one of the solar

Appearance of Radiator.	Temperature of Radiator.		Atmospheric Temperature.	Temperature of Focal Thermometer.	
	Actual.	Differential.		Actual.	Differential.
	Fahr. deg.	Fahr. deg.	Fahr. deg.	Fahr. deg.	Fahr. deg.
Light orange	2190	2149.3	40.7	178	137.3
Deep orange	2010	1969.3	40.7	173	132.3
Bright cherry red	1830	1789.3	40.7	166	125.3
Full cherry red	1650	1609.5	40.5	156	115.5
Dull cherry red	1470	1429.8	40.2	144	103.8
Dull red heat	1290	1249.0	41.0	130	89.0
Mean	1740	1699.37	40.63	157.83	117.2

pyrometer, is employed, held by a bent arm attached to the front side of the pedestal; the distance between the centre of the bulb and the focus of the concave spherical radiator being also precisely as in the solar pyrometer.

The accompanying Table exhibits the result of a trial of the testing apparatus under consideration, conducted at the Delamater Iron Works on the 4th Feb., 1871:

The following brief account has been deemed sufficient at present. The solid radiator, before being placed on the pedestal, was heated in an air furnace to very nearly white heat, and then, by means of tongs, quickly removed from the furnace and placed in the position shown by the illustration. The focal thermometer was then closely observed, its indication being recorded when the radiator had cooled so as to present a color of light orange. The indications during the succeeding stages of brightness and color of the incandescent radiator, described in the Table, were in like manner recorded. The temperature of the surrounding air being observed simultaneously with that of the focal thermometer. The time which elapsed between the first and last observation en-

tered in the Table was 29 minutes. It will be seen that the temperature transmitted by the radiator to the focal thermometer was recorded at six different stages of incandescence, the color presented by the radiant surface determining the time for observation. The mean temperature of the radiator during the experiment was 1740 deg., hence 928 deg. above the point of incandescence determined by Sir Humphrey Davy. Deducting the mean atmospheric temperature, 40.63 deg., the actual mean differential temperature of the radiant surface, the luminous heat rays of which acted on the focal thermometer, was 1699.37 deg. The mean temperature transmitted to the focal thermometer exposed to the radiant heat being 157.83 deg., while the atmospheric temperature, as already stated, was 40.63 deg., we find that a temperature of 117.2 deg. was imparted to the focal thermometer by a radiant intensity of 1699.37 deg. It will be recollected that in the solar pyrometer a differential radiant intensity of 163.9 deg. transmitted a temperature of 12.2 deg. to the focal thermometer; hence $\frac{12.2}{163.9} = 0.074$ of the temperature of the radiator was transmitted to its focus. In our apparatus for testing the correctness of the solar pyrometer, we have just seen that a radiant intensity of 1699.37 transmits $\frac{117.2}{1699.37} = 0.069$ of the temperature of the radiator to its focus. Consequently $0.074 - 0.069 = 0.005$ less heat, relatively, is transmitted by the *incandescent* radiator than by the comparatively cool radiator of the solar pyrometer. As this small discrepancy can readily be accounted for, the result of the instituted test fully establishes the truth of the doctrine which forms the basis of the solar pyrometer, viz., that the calorific energy of both dark and luminous heat rays is directly proportional to the temperature of the radiant surface. The cause of the discrepancy adverted to will be understood by the following explanation concerning the solar pyrometer. The heat imparted by the radiant to the recipient surface is transmitted through ether alone; hence neither the radiator nor the bulb of the focal thermometer are subjected to any loss by convection; while the incandescent radiator of the testing apparatus, as well as its focal thermometer, are exposed to the refrigerating influence of the atmospheric air. Obviously the heated bulb of the thermometer will cause an upward current of air, which, acting on its face, reduces the temperature, while the intense heat of the radiator will produce a still more powerful current. The consequent rapid succession of cold particles passing over the intensely heated surface will inevitably reduce the energy of the radiant heat, since the molecular motion within the heated mass cannot instantly restore the loss to which the molecules at the surface are continually being subjected by the cold current. The diminution of radiant energy from this cause, though not great, will be appreciable, and, added to the loss of heat, to which the bulb of the focal thermometer is subjected, satisfactorily accounts for the discrepancy of 0.005 under consideration; at the same time showing the absolute necessity of carrying on the operation within a vacuum.

Let us now calculate the temperature of the sun agreeably to the indications furnished by the incandescent radiator of the illustrated testing apparatus, without reference to the indications of the instrument, the reliability of which we are discussing. But in place of basing our calculations on the angle subtended by the sun from the earth, and the angle subtended by the concave spherical radiator from its focus, let us determine the solar temperature on the basis of *areas* and *distances* alone. Probably this method will be more satisfactory to the majority of readers than the one which takes no direct cognizance of areas and distances. Assuming the sun's diameter to be 852,584 miles, the area of the great circle will be $15{,}912{,}929 \times 10^{12}$ sq. ft. The diameter of the spherical radiator being 10 in. and the radius 18 in., its face presents 80.06 sq. in. = 0.556 sq. ft. Accordingly the sun's area is $28{,}620{,}377 \times 10^{12}$ times greater than the area of the concave face of the radiator. The mean distance between the sun and the earth is 91,430,000 miles, or 482,750,400,000 ft.; the distance between the radiator and its focus is 1.5 ft. The radiant heat of the sun, therefore, acts through a distance 321,833,600,000 times greater than the radiant heat of the incandescent radiator. We have demonstrated in previous articles that the temperature transmitted to the foci of con-

cave spherical radiators of equal area, is inversely as the square of their radii; and we have shown that, owing to the great distance of the sun, every part of his face may, without material error in our computations, be considered as equidistant from the earth. Hence, if we square and invert the before-mentioned distances through which the radiant heat acts, we ascertain that for equal intensity and *equal area*, the incandescent radiator will transmit $103{,}576{,}866 \times 10^{15}$ times higher temperature to its focus than that transmitted by the sun to the boundary of the earth's atmosphere. But the area of the sun, as we have stated, is $28{,}620{,}377 \times 10^{12}$ times greater than the area of the radiator; hence for *equal intensity* the radiant heat transmitted to the focus of the latter will be $\frac{103.576{,}866 \times 10^{15}}{28{,}620{,}377 \times 10^{12}} = 3618.99$ times greater than that transmitted by the sun. It will be readily seen, on reflection, that unless the temperature of the sun is 3618.99 times greater than that of the incandescent radiator, it cannot transmit to the atmospheric boundary the same temperature as that transmitted by the radiator to its focus, viz., 117.2 deg. The temperature produced by solar radiation when the earth is in aphelion, is, however, only 84.84 deg. at the said boundary; hence the sun's temperature need be only $\frac{3618\ 99 \times 84\ 84}{117.2} = 2619.25$ times greater than that of the incandescent radiator (1699.37 deg.), in order to cause an elevation of 84.84 deg. on the Fahrenheit scale at the boundary of the earth's atmosphere. Multiplying 1699.37 deg. by 2619.25, we find that the indication of the spherical radiator of our testing apparatus heated some 900 deg. above the point of incandescence, proves the sun's temperature to be 4,451,924 deg. Fahrenheit. It will be recollected that the calculations based on the indications of the solar pyrometer show that the sun's temperature is only 4,063,984 deg. The cause of this discrepancy of 0.087 has already been explained, viz., diminution of the radiant energy of the incandescent radiator, produced by currents of cold air sweeping over its face; together with the loss of heat to which the exposed bulb of the focal thermometer is subjected by the refrigerating effect of the surrounding atmosphere. Making due allowances for the loss of heat and the diminution of radiant energy referred to—inseparable from conducting the experiment in the presence of atmospheric influence—it will be found that the indications furnished by an incandescent spherical radiator, assigns precisely the same temperature to the sun as the comparatively cold radiator of the solar pyrometer. The objection urged against this instrument, that its temperature is not high enough, falls to the ground before the fact which we have established, that the intensity deduced from its indication is not affected by employing an *incandescent* radiator in place of one raised to merely boiling heat. It is specially worthy of notice that the result of the experiment with the incandescent radiator corroborates the fact established by the solar pyrometer, that while gravitating energy depends on volume multiplied by density, radiant energy depends on area multiplied by temperature; both obeying the same law in traversing space, viz., diminishing in the inverse ratio of the squares of the distances.

In view of the foregoing statements and the demonstrations contained in previous articles on the subject of radiant heat, the correctness of our calculations fixing the sun's temperature at not less than 4,060,000 deg. Fahr., cannot be controverted.

An American writer gives it as his opinion that the scrap iron of thirty years ago was good, while that of the present day is very bad. The present comparative freedom from accidents attended with loss of life is attributed to the fact that the strain upon axles is not ordinarily great, and that even a very poor axle may run for a long time without showing a defect. Even an axle of wood, carefully selected, might run for years, and be infinitely safer, with the thermometer below zero, than rotten iron.

The steam ploughs used in the United States are made in England, and imported at a cost of about $10,000 in gold, each. This price, of course, includes the customs duty on the importation of machinery.

BREAKWATERS.

From "The Mechanics' Magazine."

The whole construction of breakwaters turns upon the theory of waves. If their action be not thoroughly understood and its effects provided for in a scientific and skilful manner, the strongest and most solid description of work will yield in course of time to the never-ceasing attacks of the water. A breakwater, as the name implies, is a structure designed to arrest or break the force of waves. It may be either of a temporary or permanent character, stationary or movable, and may be constructed of timber, stone, iron, and many other materials. Natural breakwaters exist in abundance, and are the results of long-continued aqueous action. They generally owe their origin to the gradual undermining of lofty cliffs by the sea. Little by little the debris accumulates until it rises above the surface of the water, and then constitutes a natural rampart, and serves as a protection against the further disintegration of the parent rock from which it sprung. Breakwaters are frequently constructed expressly for the purpose of sheltering exposed coasts and preventing the inevitable encroachments which the sea would certainly make but for the artificial precautions adopted. It is well known that whole villages have been gradually encroached upon by the sea, and ultimately engulfed. This is especially remarkable on the eastern shores of our own country.

Solid breakwaters which oppose a direct resistance to the force of the waves are during storms subjected to great violence. The maximum altitude of waves in these instances may be assumed equal to 20 ft., which exert a force upon the breakwater equal to the hydrostatic pressure of a column of water of that height. It is easy, on this assumption, to calculate the minimum thickness to be given to the stone-work. In his "Principles of Geology" Sir Charles Lyell quotes an example of the remarkable force of waves—a mass of rock, equal to 300 cubic ft., and weighing about 28 tons, was transported to a distance of nearly 90 ft. The ancients were well acquainted with the tremendous effort which waves are capable of exerting, and were in the habit of using enormous stones in their works for sea defences. Josephus mentions that Herod laid the foundations of a marine engineering work with stones containing over 4,000 cubic ft., complete monoliths, in fact. While there is, no doubt, an advantage in the size of the stones, yet it must not be forgotten that in the present day we have have attained to a degree of science and skill in construction which enables us to dispense in some measure with mere size and weight. These last-mentioned features were essential to construction in the barbarous ages; nevertheless, if there is one class of engineering works more than another in which large stones are of value, it is that connected with sea defences. When large stones are not to be procured the proper step is to bind those that are used so consistently together that they act as one mass. This was accomplished by Smeaton in the Eddystone Lighthouse. All the stones are so intimately dovetailed, joggled, dowelled, and cramped together, that it is impossible for any one to move in the slightest degree independently of its neighbors. The whole structure must yield together, if it yield at all. It cannot be destroyed in detail. It resists the forces that for more than eighty years have been incessantly endeavoring to destroy it by its entirety, and not by the strength of any of its component parts. As with a lighthouse so with a solid breakwater. The stones of the latter should be sufficiently large and sufficiently well bound together to act as one mass. Sometimes, in spite of all precautions, accidents will occur. During a tremendous storm about thirty years ago some of the largest blocks in the Plymouth breakwater were uprooted and thrown bodily into the water. They were not loose unbedded stones, but cut and squared blocks thoroughly bonded together in cement and made as solid as possible. Whatever may be the particular direction of the force of the wave, whether vertical or horizontal, or both, it is merely a question of so much weight or pressure. Obviously, therefore, a certain weight of material must be provided in order to afford an adequate resistance to the action of the water. If

this weight cannot be obtained in separate parts of the structure, that is, in each individual stone, it must be insured *en masse*. Although there is a good deal of information extant upon the altitude, weight, and pressure of waves, there is still great want of a series of accurate reliable experiments made at different times of the year and in different localities.

Having briefly noticed the solid type of breakwater, we may now glance at the other, in which, instead of the principle of direct resistance being adopted, that of the reverse is made use of. Instead of defying and withstanding the force of the waves, the other method consists in yielding to it, and allowing it to gradually spend its fury by being divided, or broken up, as it were, so that it becomes quite harmless when it arrives to landward of the breakwater. This may be effected by a stationary iron breakwater, but is infinitely better accomplished by a floating one. Patents have been taken out for floating breakwater many years ago, but as yet little or nothing has been done with them. One of the reasons, probably, is that timber was the material selected, and another that the true principle was not hit upon. The great point to be insured is the gradual but complete disintegration, so to speak, of the wave. It should be literally cut to pieces by the breakwater, and deprived of every atom of violence it possesed when first coming in contact with it. This is what is well accomplished in Saunders's breakwater, in which wrought iron is the material employed, and the necessary strength obtained by a scientific system of bracing. A great, but at the same time unfounded objection alleged against floating breakwaters is that they break away from their moorings. Many engineers of undoubted attainments share in this opinion. It is possible that they may not have seen a good design of a floating breakwater properly moored. The fact is that it is not the mooring that has to be attended to, but the design and construction of the breakwater itself. It may at first sight appear somewhat odd that if the "Great Eastern" can be held at her moorings any question could arise about holding a floating body, weighing in separate sections about 60 tons. But the cases are not analogous. A ship always rides at her anchors "end on." A floating breakwater must ride broadside on. It depends altogether on the construction, whether it can do this or not. It is needless to point out the great importance that attaches itself to the subject of floating breakwaters. Both at home and abroad there is abundant scope for them. There are, comparatively speaking, very few localities in which the large outlay required to construct a solid breakwater of masonry can be incurred. Consequently, these places are unprovided with any such protection, and it is no wonder that their trade suffers terribly in consequence. A floating breakwater supplies all the accommodation given by a fixed permanent structure at about a tenth of the cost, and can, moreover, be used temporarily at different stations, as might be required.

It is proposed to consolidate the Government lands between the Capitol and the White House, and form a fine park two miles long and half a mile wide, and lying parallel with Pennsylvania avenue, at a distance of from one to four streets from that thoroughfare. There is an intention to provide in the new park a circular drive five miles long, and to have lakes, fountains, walks, and zoological and botanical gardens, and all the appurtenances of a pleasure ground for an enlightened people.

The "Scientific American" says the area of the coal fields of the carboniferous age, lying within the limits of the United States, has been estimated at 150,000 square miles. The area of Ohio is not less than 10,000 square miles, or quite equal to that possessed by Great Britain, and far in excess of that of any other European nation. The annual coal production of Great Britain is over 100,000,000 tons; in Ohio it is now about 3,000,000 tons.

Agincourt, 28, iron-clad, Captain Beamish, at Devonport, where she is to have her defects made good, is to be fitted with Admiral Inglefield's steering apparatus, at a cost of £900.

ON THE CALCULATION OF EARTHWORK TABLES.

By GEO. B. LAKE, C. E.

The calculation of any extended table of quanties represented by an equation, is, at best, exceedingly laborious.

The well-known principle of constant differences enables one to calculate quantities with a very small part of the labor required in the method of direct substitution, and, at the same time, insures accuracy. A careful study of the results of this principle will enable us to make a still further great reduction in the required amount of labor.

Let us first notice a table of quantities represented by an equation of the first degree. Take, for example, the equation $y = \frac{1}{16} x$:

x	y	d
0	0.0000	
1	.0625	.0625
2	.1250	.0625
3	.1875	.0625
4	.2500	.0625
5	.3125	
6	.3750	
7	.4375	
8	.5000	
9	.5625	
10	.6250	
11	.6875	
12	.7500	
13	.8125	
14	.8750	
15	.9375	
16	1.0000	
17	1.0625	
18	1.1250	
19	1 1875	
20	1.2500	

By an examination of the table, we find that the last two figures of the decimal in the column containing values of y are repeated every four places. This is because the product of four into the constant difference, .0625, shows ciphers for the last two figures.

For a like reason, three figures are repeated every eight places, and four every sixteen places.

It is evident that to continue this table we have only to repeat the decimal figures already found, and increase the integral part by one at the commencement of each repetition.

Since the value of d depends on the coefficient of x, it will be easy to determine from the form of the equation the point at which the repetition of figures will commence.

A similar result will be found in tables of quantities which have the second order of differences constant.

From the equation $y = x + \frac{1}{15} x^2$ we obtain the following table:

x	y	d_1	d_2
0	0.0000		
1	1.0555	1.0555	
2	2.2222	1.1666	.1111
3	3.5000	1.2777	.1111
4	4.8888	1.3888	.1111
5	6.3888	1.5000	.1111
6	8.0000	1.6111	.1111
7	9.7222	1.7222	.1111
8	11.5555	1.8333	.1111
9	13.5000	1.9444	.1111
10	15 5555	2.0555	
11	17.7222	2.1666	
12	20.0000	2.2777	
13	22.3888	2.3888	
14	24.8888	2 5000	
15	27.5000	2.6111	
16	30.2222	2.7222	
17	33.0555	2.8333	
18	36.0000	2.9444	
19	39.0555	3.0555	
20	42.2222	3.1666	
21	45.5000	3.2777	
22	48.8888	3.3888	
23	52.3888	3.5000	
24	56.0000	3.6111	
25	59.7222	3.7222	
26	63.5555	3.8333	
27	67.5000	3.9444	
28	71.5555	4.0555	
29	75.7222		
30	80.0000		
31	84.3888		
32	88.8888		
33	93.5000		
34	98.2222		
35	103.0555		
36	108.0000		
37	113.0555		
38	118.2222		
39	123.5000		
40	128.8888		
41	134.3888		
42	140.0000		
43	145.7222		
44	151.5555		
45	157.5000		
46	163.5555		
47	169.7222		
48	176.0000		

In this table we find that the decimal figures in column d are repeated every 9 places. The reason is obvious. We find, also, that the decimal figures in column y are repeated every 18 places. This results from the following considerations: The value of y for $x = n$ is the sum of the first n terms of the series of first differences. The $(n+1)th$ term the series of first differences, equals the first term plus n times the second or constant difference. If the value of y corresponding to $x = n$ becomes an exact integer at the same time that $n \times d_2$ becomes an integer, the decimal figures will commence to repeat at that point.

It will be noticed in this table, that the decimals in column y are repeated in inverse order every 9 places. This will occur whenever a term in column d becomes an exact integer, or whenever the sum of two consecutive terms is an integer.

It is plain, that after the commencement of the repetition of figures in this or in any similar table, the decimal part of the quantities in column y may be written without further computation; and in order to be able to write the entire quantities, we have only to discover *the law of increase* of the integral portion. This is easily done. In the table we see from the value of the terms in column d., that the integral portion of the quantities in column y will, at first, increase by the regular addition of 1. This will continue until the sum of the decimal part of the quantities in column d shall become equal to or greater than a unit, in which case there is 1 *to carry*, and the integral part of the value of y is increased by 2.

And so on, until the term in column d. becomes greater than 2, after which the *regular* integral increment in column y. is 2, and this become 3 when there is 1 to carry on account of the decimal portion. We do not need to continue the series d, in order to know when to carry on account of the decimal and when to increase the regular increment; for, in general, whenever the decimal portion of the quantities passes from greater to less, there is 1 to carry; and to learn how often to increase the regular increment, divide 1 by the value of d_2. The quotient is the number of terms which it is required to know. This may also be readily learned from the form of the quantities themselves. Whenever the integral part of the series in column d is increased—that is to say, whenever the integral increment of quantities in column y is increased, it will be noticed that the decimal part of the quantities in column y will *gradually decrease* to the point where the change is made, and beyond that it will *gradually increase*.

Thus, we see that in any table similar to the one we have considered, after we have computed the quantities up to the point where a repetition of the decimal figures commences, we may continue the table to any desired length by merely *copying* the decimals in their proper order and at the same time giving the proper increment to the integral portion; and since each quantity depends for its accuracy on those which precede it, the detection of errors is almost a certainty.

It is not essential to the accuracy of the principles above stated, that the repetition of figures should include the entire decimal portion of the values of y. The value of d_2 being fractional, if a certain number of ciphers immediately succeed the decimal point, there may be the same number of decimal figures in the values of y not covered by the repetition. If, on the other hand, the value of d_2 is not fractional, there must be the same number of integral places in the value of y included in the repetition as are found in the value of d_2.

Like results might be shown in tables computed from equations of higher orders, but it is unnecessary to continue the investigation, since the equations used in the tables of Excavation and Embankment are seldom, if ever, of higher degree than the second.

NOTE.—At the bottom of page 288, March No., the quantity

$$\tfrac{1}{6}\, l\, \tfrac{1}{2}\, [r\, h_1{}^2 + \tfrac{1}{2}\, r\, h_2{}^2 + \tfrac{1}{2}\, r\, (h_1 + h_2)^2],$$

should be $\tfrac{1}{6}\, l\, [\tfrac{1}{2}\, r\, h_1{}^2 +$, etc.

At the top of page 290, the first quantity in column B should be .0648, instead of .0000, as printed.

A RIFLE tower has been erected on the upper deck of the "Lord Clyde," armor-plated screw ship, in the basin at Keyham. Communication with the lower deck is provided for by means of a scuttle inside the tower, which is placed immediately abaft the bridge.

ON PHONIC COAST FOG-SIGNALS.*

By MR. A. BEAZELEY, M. Inst. C. E.

From "The Engineer."

The coasts of these islands being liable to fogs and mists, it was surprising that the subject of fog-signals, for the guidance and warning of the mariner under such circumstances, should have received so little attention; and beyond an occasional notice or a brief suggestion among scientific journals, there were no traces of systematic research and experiment. It was by some supposed that great power and long range of sound were not essential to fog-signals, inasmuch as it was said fogs usually occurred in comparatively calm weather. This, however, was not the case, so far at least as regarded the coasts of Great Britain; for in the years 1868-69 fogs prevailed on the Yorkshire coast 51 times, at the entrance of the Bristol Channel 125 times, and near Holyhead 170 times, with a total duration of $254\frac{3}{4}$, $713\frac{3}{4}$, and $698\frac{1}{2}$ hours respectively; when the strongest winds were from the seaward, and varied in force from a mean of 4.55 and a maximum of 8 on the eastern coast, to a mean of 4.47 and a maximum of 9 on the western coast. But even where fogs were not usually attended by high winds the necessity of power and range in fog-signals was in no way diminished; for a heavy snow-storm, or thick driving sleet and rain, which often accompanied a gale of wind, were quite as blinding and bewildering as the densest fog.

In 1863 a committee of the British Association memorialized the President of the Board of Trade with a view to induce him to institute a connected series of experiments as to the effect of fog upon various sounds. It was then shown that the laws which governed the action of fogs in deadening sound were at present so imperfectly understood that such a thorough and scientific inquiry was much to be desired, and was, in fact, essential to any real addition to the knowledge of the subject; without which all investigations of isolated cases were little better than a vague groping in the dark. It was also pointed out that experiments during clear weather could not be accepted as affording satisfactory evidence of the value of any signal during fog.

The general tendency of fog to intercept or modify sound in its passage through the air, and the absence of reliable data as to the precise conditions which affected or varied the intensity of its action in this respect, had led to the suggesting whether water might not be employed as a medium for the transmission of fog-signals. The experiments of M. Colladon on the Lake of Geneva in 1826 were referred to, as well as the recommendations made in 1851 by Mr. Babbage to the United States Lighthouse Board, and Professor Hennessy's views on the same subject.

It was stated that the instruments in use for fog-signals were gongs, bells, guns, whistles, and trumpets—the two latter sounded either by steam or by condensed air, and a detailed description was given of these several appliances—whether in use or proposed—and of the experiments that had been tried to ascertain their efficacy. In conclusion it was remarked that, upon a review of the various fog-signals which had been mentioned, it was found that the whistle and the trumpet stood out prominently as regarded power and manageableness. Guns, besides their heavy working expenses, had the disadvantage of requiring a longer interval between the signals, and of entailing continuous work upon the attendant. It appeared, therefore, that it was to the improvement, and the augmentation of power of the two former, that a more efficient instrument must at present be chiefly looked for. Whatever might be the fog-signal adopted in practice, power of sound and certainty of action were indispensable conditions. Better, it has been said, no signal at all, than one that could not be relied upon; and, undoubtedly, if the mariner was led to expect a signal at a certain place, and at sufficient range to insure time to act upon its warning, it ought to be so heard with unfailing certainty. Among existing signals there were some which, in ordinary fog and moderate weather, would fulfil these requirements; but it was doubtful how far they would act to windward against a heavy gale. The howling

* Abstract of a paper read before the Institution of Civil Engineers, London.

of the wind, the groaning and creaking of the hull and spars, the shock and roar and thunder of the sea, the drenching, blinding spray, the fierce blast, the thick mist — those were the antagonists against which the fog-signal would have to try its powers; and powerful indeed must be its voice if it afforded in time a friendly warning.

There was another point with respect to fog-signals, where in connection with a lighthouse, which ought not to be overlooked; namely, the importance of making the character of the sounds, and their duration and intervals, correspond with the character of the light. The fixed light might be denoted by continuous sound, or better by a quick succession of sounds; the revolving and the flashing light by corresponding blasts; and colored beams alternately with white light, by a lower and a higher note alternating in a similar manner.

One difficulty in the way of employing, at rock lighthouses, any fog-signal but a bell, or such other instrument as could be sounded by the application of simple clock-work, was the unsuitableness of such buildings for the reception and working of a steam or caloric engine, and the severe labor which would be entailed upon the keepers by the use of powerful machinery worked by hand. But the author still entertained the opinion, which he formed 16 years ago, that the vast dynamical power afforded by the rise and fall of the tide would yet be utilized and applied to the compression of air for the purposes of fog-signals at such stations.

ON THE SHIP-WORM AND THE MEANS OF PREVENTING ITS RAVAGES.*

By DR. ADOLPH OTT.

From "The Engineering and Mining Journal."

The extensive destruction of submarine works caused by the teredo navalis or ship-worm, prompted the Royal Academy of Sciences in Amsterdam, in the year 1858, to appoint a committee to investigate the natural history of this singular animal, and the remedies proposed for preventing its attacks. The results of these investigations, of which we shall only present the most important ones, have now been published by E. K. von Bumhauer in the "Mededeelingen d. k. Acad. Wetensh."

The mode in which the boring mollusks —for there are several of them—perforate all bodies, from the softest wood to the hardest stone, has been the subject of various opinions; yet, it is now generally considered by naturalists, that the rock-boring mollusks are capable of secreting a liquid which corrodes stone, while others, like pholas and teredo, bore by physical action.

As to the teredo navalis or ship-worm, it belongs to the acephalous or headless mollusks, the same zoological division as the oyster. It is enveloped by a shell and mantle, which form a sort of sheath communicating by two siphons with the exterior. The shell itself consists of two valves of equal size, which are united by a fold of the mantle in such a manner as to permit of only very slight movements. The surface of the shell, upon examination with a magnifying glass, presents a striated and indented appearance, especially towards the margins. (The wedge-like teeth present a length of 1.65 lines.) These striations are not uniformly distributed over the shell, but upon the anterior, thicker, and spoon-like part, they run nearly in a straight angle towards those of the centre. It is estimated that both valves together bear 20,000 teeth. We will remark that as long as the animal grows, new and sharper teeth are constantly formed, which substitute the older and blunt ones.

The fecundation takes place by the contact of the siphon with that of an individual of the other sex. The females, of which there are about twenty to one male, lay eggs. These are expelled in June through the siphon, and on the fourth day are already transformed into larvæ, which are capable of attacking wood.

*A paper read before the Polytechnic Club of the American Institute on the 27th Jany, 1871.

M. Kater has seen them at the end of June in large masses upon wood, and on the 15th day of July he discovered grown up mollusks in its interior.

The teredo bores at first a very small aperture in a direction perpendicular to the surface, but it changes its route after a while, in order to follow the direction of the fibres. In the first stage of its development, this imperceptible, but none the less dangerous miner has only one siphon, but later another is formed. They are of equal lengths. Both seem to serve for secreting the fæces, which mostly consist of pulverized particles of wood, forming a very fine white mass. It seems that the shorter siphon is principally used for this purpose, while the longer one serves for the reception of food, consisting of infusoria, diatomes, and other lower organisms. The bore-worm requires pure, clear water, with a certain amount of salt. If the sea-water is mingled with much fresh water, the animal dies. It continues to grow in the wood. At first the diameter of the groove is only half a millimetre, but gradually reaches five millimetres and more. The teredo itself acquires a length of from 1 ft. to 1 ft. 4 in. It usually attacks that portion of the wood lying between low and high water marks, and if it it is sometimes found above the water, it is because the timber has retained a sufficient degree of moisture. At Ostend, where the teredo abounds, it has been found in all situations below 6 ft. 3 in. (1.90 met.) above the low-water mark of spring tides.

In its abode, the margin of the mantle secretes calcareous matter and deposits it on the inner wall of the cell. This deposit is at first quite soft, but soon becomes hard. Between this calcareous layer and the animal, there is, however, left sufficient space, so as not to hinder the little miner in its movements. Strange it is, but however multiplied may be their tubes in the same piece of wood, they never mingle, so that between two tubes there is always left a partition wall, though sometimes a very thin one. "The wood," says Louis Figuier in his admirable book ("The Ocean World"), "is thus attacked at a thousand diverse points, until it is invaded and its entire substance destroyed. Submarine constructions upon which bridges are built are often riddled and perforated. They appear to all outward examination as solid and perfect as at the moment they were first erected; but they yield to the least force, bringing ruin and destruction on the edifices they support. Ships have thus been silently and secretly mined, until the planks crumbled into dust under the feet of the sailors. Others have gone down with their crews, owing to the ravages of these relentless enemies, which are horrible from their unapproachable littleness."

If removed from the salt water, the teredo dies within 24 hours, while if taken out of the wood, it continues to live in sea water for 3 or 4 days. Its abode in the ligneous tissue is therefore a condition of life. In a worm belonging to the annelidæ (lycaris fucata), which is always found in the wood excavated by the teredo, we find an enemy of the latter. This parasite attaches itself to the entrance of the tube, sucks itself to the teredo and devours it slowly. It then seeks another victim. It has a length of from 4 to 6 in., and is provided on both sides with numerous hairy feet. Behind the head, which is provided with a powerful masticatory apparatus, there are 4 pairs of tubular appendages.

Formerly, it was supposed that the naval worm was a native of the tropical zones, but the discovery of closely related species in the tertiary layers, and various discoveries of excavated pieces of timber in more recent deposits, have proved the fallacy of that supposition.

The circumstance that the teredo appeared in enormous hosts in the years 1731, 1770, 1827, 1858 and 1859, has also led to the discovery that an unusually large increase takes place whenever by lack of rain the rivers run low, thus augmenting the proportion of salt in the sea near the coasts.

For a long time past, various means have been proposed in order to preserve timber used for marine purposes from the attacks of the teredo. To gain an insight into the efficiency of these alleged remedies, the Academy of Sciences of Amsterdam instituted a series of experiments, which were conducted by Messrs W. Vrolik, P. Harting, D. Storm-Briegsing, S. W. L. von Oordt, and E. H. von Baumhauer.

In reporting these experiments, the author, Mr. E. H. von Baumhauer, calls

attention to the fact, that upon the great devastations caused by the teredo in 1858 and 1859, a number of secret remedies were offered to the Government. The scientific committee had considered it its duty not to leave any one of them untried, although there were many among them which it could be foreseen would be inefficient. And in order that no objections could be made upon the part of the members, they were allowed to conduct the trials themselves.

The experiments were made in the harbors Kissingen, Harlingen, Stavoren and Niervendam, with piles of oak, pine and fir, some of which were prepared and others left in a natural condition, so as to serve as counter-proofs. The piles were mostly 3½ ft., long and of a cross-section of 2 to 3 sq. ft. Three classes of experiments were made :

1. The external coating, with paints and other substances.

2. The impregnation of the wood with substances by which the appearance of the surface as well as that of the interior is changed.

3. The use of very dense exotic wood.

In experiments of the first class, the following compositions were tried :

(1.) A composition of Classen, kept secret.

(2.) A metallic paint of Classen, also kept secret.

(3.) A composition of Brinkerink, consisting of Russian tallow, coal tar, rosin, sulphur and powdered glass, applied warm and after the wood had been roughed. The layer was several lines thick.

(4.) A composition of Rijhwyk, somewhat similar to No. 3.

(5.) Paraffine varnish, obtained by dry distillation of peat.

(6.) Coal tar applied cold and warm in several layers upon wood externally carbonized. Into some piles holes were bored, which were filled with hot tar and then shut, so that the tar could penetrate into the interior. Some piles were also covered with a mixture of tar and oil of vitriol, to which sal ammoniac, turpentine and olive oil had been added.

(7.) Turpentine with linseed oil paints ; among them chrome green and verdigris.

(8.) The surface of the wood was merely carbonized.

The thus prepared piles were immersed in the water at the end of May, 1859. When taken out in September of the same year, it was found that, with the exception of No. 6, none of those alleged remedies had proved effective. The timber coated with the composition No. 6 showed only traces of attacks of the teredo, but in the fall of 1860, or after one year and a half, it presented a number of excavations.

The results of these experiments convinced the committee in the most satisfactory manner that no external application furnishes protection. Although such a one may prove useful for some time, the slightest crack or abrasion, produced by the action of the water, ice, or other causes, will form an entrance for the young teredo.

It may here be well to say a word about the coating with iron nails, which although very expensive, is still largely in use. If this means is to afford protection at all, the square heads must well join together, and the piles, before being immersed, ought to be exposed to the action of the atmosphere, so that the surface of the iron may rust well and fill the spaces between the heads. And yet the Committee on Examination reports that some piles, coated in this manner, exhibited, after years, perforations of the ship-worm, although they had been covered with a layer of iron rust over an inch thick.

Concerning the sheathing of lock-gates with iron, copper, or zinc plates, a process often used, it is evident that if this covering remained complete no penetration of the wood could possibly occur. Experience, however, has shown that these plates furnish no enduring protection, owing to the fact that it is impossible to maintain an unbroken or unabrased surface. It has been discovered that nature itself affords a better protection in the case when sea-shells attach themselves to the gates before the larvæ of the teredo have had time to begin their attacks.

In experiments of the 2d class the following alleged preventives were tried :

1. Sulphate of Copper or Blue Copperas.—The piles were impregnated in Amsterdam, but it was found in the summer of 1859 that this process was unsuccessful. Yet, in order to be certain that this was really the case, the committee ordered from Paris 2 logs of beech-wood with the bark, 2 without the bark, and 2

logs of pine-wood, all of which had been saturated with a solution of sulphate of copper. These pieces also proved valueless, and the experiments only confirmed the results obtained by the engineer Noyon.*

2. Sulphate of Iron or Green Vitriol.

3, Acetate of Lead.

Impregnation with the salts yielded negative results; also,

4. Soluble Glass and Chloride of Calcium.—In order to form a silicate lime in the pores of the timber the piles were first saturated with the soluble of glass and afterwards with chloride of calcium. Before they were immersed in the water they were exposed to the air for half a year, so as to effect a perfect chemical union. In March, 1862, these piles were placed in the water, and, on examination in October of the same year, it was found that the teredo had caused great ravages.

5. Creosote Oil.—This is a product of the dry distillation of coal tar, which, by a second distillation, is purified from the most volatile as well as from the heavy oils. In the month of May, 1859, pieces of wood saturated with oil of creosote were placed at Vlissingen, Harlingen, and Stavoren, in the sea. In September of the same year they were all found free from worms, while other unimpregnated pieces, that had been placed beside them, had been thoroughly invaded. Another trial was made in July, 1860, with ten piles of oak and pine, treated with creosote; and later, piles of beech and poplar were employed that had been treated by Boulton, in England.

All these piles were examined in the fall of 1862, '63, and '64. While those that had been left in their natural condition had been thoroughly invaded, the oak only showed traces of the worm; but, in sawing one of the oaken piles through, the wood was found to have been very imperfectly saturated.

On investigation in the year 1864 it was found that the piles of pine, beech and poplar, treated by Boulton, in England, were perfectly sound, although exposed to the action of the teredo for 3 years; indeed, not the least excavation could be discovered. After a layer of a certain thickness had been cut off from them they were again immersed, and proved also this time to be perfectly worm-proof.

The same satisfactory result was obtained with piles impregnated by a company in Amsterdam. They had remained in the water for 5 years. In none of this wood, not even in that which had several times been deprived of its surface layers, could a trace of the ship-worm be discovered. Of the unprepared wood that had been served as a counter-proof, nothing but the head-pieces over the water had been left; the rest had become a spongy mass, of no strength.

In all the impregnated piles of oak there were here and there traces of the teredo, owing probably to the circumstance that the oil penetrates with difficulty into this kind of wood. It had finally been recommended to the committee to use petroleum, but, owing to its high price, no trials were made with it.

Under the third head various exotic woods, some of great hardness, were tried. However, the experiments made with them were only a few. It can only be said with certainty that some species of wood from Surinam, American oak, and several others, were not spared.

The Committee on Investigation also received a heavy piece of Guajac wood, which had been laying for five or six years in the sea at Curacoa. Being thoroughly perforated, it afforded the best proof that even the densest wood is useless for submarine constructions.

The committee finally received communications on wood reputed to be poisonous to fishes, but has had no opportunity of proving or disproving these statements. It was proposed, therefore by the Dutch Government to make inquiries in the East as well as in the West Indies.

The report of the committee sums up with the following conclusions:—1. That mere external coating of the timber with paint or other substance affords no protection; since it is impossible to maintain an unbroken surface, the young teredo will enter the slightest crack or abrasion. The use of copper, zinc or galvanized iron plates is too expensive for most occasions; and even these become of no use when broken. 2. Impregnating wood with soluble inorganic salts which are poisonous to animal life, furnishes no protection against the worm. This is due to the fact that the sea water soon

* Sur l'inefficacité du procédé Boucherie en eau de mer. Annales des Ponts et Chaussees, Mars et Avril.

dissolves away their strength, and that the worm does not devour or digest the wood bored out by means of the shelly jaws. 3. The hardness of the wood and its poisonous character, so far as known, are of no avail. 4. Creosote oil is so far the only substance met with that constitutes a true protection against the worm. Attention should therefore be directed to the best and quickest methods of saturating the wood with this material, and to the kinds of wood most absorbent of it. The creosote oil doubtless owes its peculiar powers in the respect just indicated mainly to the carbolic and cresylic acid it contains, and we have thus another illustration of the important applications to be made of the latter substances in our domestic and industrial economy.

Similar testimonials as to the efficacy of creosoting have from time to time been given by eminent engineers and scientists pursuing the study of applied science. In a work published in Paris in 1868, and entitled "Memoir sur la conversation des bois á la mer," Mons. A. Forestier states, for instance :

"Our studies and experiments have entirely convinced us that of all the numerous processes hitherto known, the only one thoroughly efficacious is that which consists in thoroughly impregnating wood with creosote."

In his evidence, given before the Select Committee on Harbors of Refuge, Mr. Abernethy said :

"I am convinced that timber, when creosoted, is not subject to the action of the worm, as far as my actual observation goes ; and in that case probably I am understanding it when I say it would last for half a century at least."

The earliest wood creosoted, and exposed to the sea in harbors, was at Lowestoft.

At the meeting of the Institution of Civil Engineers, Mr. T. E. Harrison remarked, that the entrance gates of the Monk-Wearmouth docks at Sunderland, which had been constructed of yellow pine, creosoted 20 years ago by Mr. Brunel, were quite sound, but portions of kyanized timber, used in the same works, had been attacked by the worm to a considerable extent.

The use of creosote oil for preserving wood was introduced in 1838 by John Bethell. In the beginning the oil was valued merely as an antiseptic, but it is now generally agreed that it is not less useful in filling the pores of the timber so as to exclude air, water, and putrescent matter.

Concerning the plans proposed for impregnating wood with creosote, we propose to briefly consider the most remarkable ones.

The Pressure Process.—The wood and liquid being contained in, and nearly filling a closed and strong iron receptacle, more liquid is pumped in till a high pressure is attained and the liquid is forced into the pores of the wood. The pressure required for the purpose approaches 200 lbs. to the sq. in., and the apparatus is consequently very heavy and very expensive. Only well-seasoned and dry wood is suitable for the process, as it is evident that if the pores of the wood be occupied with sap, no amount of simple pressure will condense the sap to permit the entrance of the preservative liquid. The great cost of setting up and working this process, and the fact that it cannot be effectively used for unseasoned lumber, have prevented its extensive introduction into the United States.

The Vapor Process.—This process was first carried out on an extensive scale by Lucken in 1811, and was revised in England by Frank Moll, in 1835, and quite recently by Mr. L. S. Robbins in the United States, who brought it before the public as a "Discovery of one of the Lost Arts of the Egyptians." This plan was proposed at a time when the value of antiseptics was overestimated, and when the necessity of sealing the pores of the ligneous tissue was overlooked. It was also supposed that by simply exposing the wood to the vapor of coal tar, a sufficient amount of the antiseptic would be carried into the pores to afford perfect protection. Leaving out of question the injury to the wood by the high heat necessary to volatilize the products employed (from 400 to 700 deg. Fahrenheit), it is evident, since the space occupied by creosote vapor is 1100 times that of the same weight of liquid creosote, no available amount can be got into the wood. And, even if it should be completely permeated, no useful end will be attained, owing to the fact, that the vapor on condensation will leave the pores empty.

The Seely Process.—The writer has

already had occasion to call attention to this process, by which, within the past three years, large quantities of railroad, dock, and pavement timber have been successfully treated. Although one of the most recent processes, it has attained a high reputation, and is already spoken of as the only one fulfilling the requirements of scientific and practical investigation.

The process, in brief, consists in subjecting the wood to a temperature above the boiling point of water and below 300 deg. while immersed in a bath of creosote oil for a sufficient length of time to expel the moisture. When the water is thus expelled, and the pores contain only steam, the hot oil is quickly replaced by a bath of cold oil, by means of which change the steam in the pores of the wood is condensed, and a vacuum is formed, into which the oil is forced by atmospheric pressure and capillary attraction. Among the advantages of this plan, the following may be named: the thorough air-drying which is required by the pressure process is obviated; the expulsion of the sap, and the amount of oil forced into the wood, is perfectly under the control of the operator; any desired fraction of the vacuum of the pores may be filled at pleasure. On examination of wood saturated by Seely's method of treatment with the microscope, the writer found every pore completely filled with oil, and this not only on the surface, but also in the centre of the piece examined.

THE NEW WROUGHT-IRON BRIDGE AT BRIDGEPORT, CT.*

This bridge crosses the Pequonnock river at an angle of about 60 deg., and comprises a total length of 845 ft. Of this length 345 ft. are taken up on the west side by an embankment between retaining walls, gradually rising with a grade of 1.66 ft. per 100. The superstructure of 420 ft., total length, consists of 3 fixed spans of 70 ft. each, and one draw-span of 210 ft. over all (centre measurements). The roadway on the permanent spans *is 30 ft. in the clear between trusses*, but is contracted at the draw-span to 23 ft., as shown on the drawing. The sidewalks on either side of the trusses are 6 ft. in the clear, except on the draw-span, where they are 5 ft. The above are unusual dimensions, but so required by the Commissioners, to accommodate a heavy and increasing traffic.

The principle of truss adopted will be at once recognized as that first recommended by Mr. Whipple, and from the fact that the posts are vertical, this system commends itself for city bridges (where trusses are unavoidable), for the reason that such posts are susceptible of more æsthetic treatment than inclined ones. The question of the appearance of such structures has too often but little consideration from engineers and town committees in these days of close competition, which is much to be regretted, for certainly an object that is so prominent in cities and towns as a bridge, observed from necessity perhaps more than any other public or private work, demands something more than simple constructive or economical considerations.

The trusses of the permanent spans are 5 ft. $8\frac{3}{4}$ in. deep, and are broken up into 12 rectangular panels. Each upper chord is 19 in. wide, and is composed of varying thicknesses of boiler-plate riveted to two 6-in. rolled channel bars and one 6-in. flanged beam. The lower chord is formed from weldless links, whose heads have been made by upsetting. These links, the length of one panel, are joined by carefully turned pins, which pins also form the connection for the diagonal braces and posts. The braces are also links, formed as above, the connection with the upper chord being by means of a pin passing through the channel bars.

The vertical posts are in pairs, and are the patent wrought-iron column of the Phœnix Iron Company. They are formed by riveting together 4 segments of a true cylinder by means of flanges which are turned outward. Cast-iron caps and bases, turned and fitted, form the bearings between the chords. It should be remarked, in connection with the braces, that the counter rods have turn-buckles upon them, forming the only adjustable feature in the truss. The floor-girders

* From a paper read before the American Society of Civil Engineers, by ALFRED P. BOLLER, C. E., Member of the Society.

(of which there are 3 in each span) are trussed 2½ ft. deep, as shown on drawing, and have their bearing upon the base castings through the medium of projecting brackets. The upper member consists of two 6-in. channel bars, passing either side of posts with a plate 10 in. wide riveted on top. The channel bars project beyond the trusses to support sidewalks. Horizontal sway braces, intersecting in a ring, are attached to the floor-girders at their bearing points on the trusses. The 3-in. spruce planking which forms the roadway is supported upon longitudinal stringers of 4 × 12 white pine placed 18 in. apart. The sidewalks are planed yellow pine plank 2 in. thick. The railing is of simple but effective construction, and made from two very light tee bars with diagonal strips riveted to the webs. The diagonals intersect in a cast-iron boss, and the top rail is finished off with a half round strip riveted upon it.

The draw-span, at present the largest self-sustaining draw in the Eastern States, is supported upon a Parry-antifriction pivot and a circular drum 28 ft. diameter, of wrought and cast-iron, bearing upon chilled wheels in a live ring. At intervals heavy diagonal rods connect the bottom flange of the drum with the pivot, while light counters run in the opposite direction, as shown on the drawing. There are six points of contact between the turn-table and bridge, the middle contact being made by means of a heavy cross-girder.

The trusses of this span are placed 23 ft. 6 in. apart, centre to centre, and from the depth of the permanent spans at the free ends rise in an easy curve to a depth of 12 ft. 3 in. at centre. An important saving of material would have resulted from an increased central depth, but the Commissioners desired, if possible, that the trusses should not be carried so high as to necessitate horizontal connection between the top chords. It may be remarked, also, that the height adopted allowed of a curve in more pleasing proportion to the depth of the fixed spans. Owing to this arrangement, it was deemed desirable to form the top chord of weldless links, the voids between adjacent links being filled in with packing pieces, wedged in place with keys. In addition to this, the two separate lines of links on either side of posts were further stiffened laterally by means of light castings.

The usual riveted arrangement of a top chord for such purposes would have required a large excess of metal, for self-evident constructive reasons.

The lower chord of either truss is composed of four 9-in. channel bars, of increasing weight from end to centre. These bars are strongly braced together, and their continuity is assured by splice-plates and rivets. The posts are in pairs, as in the fixed spans, and are also wrought-iron columns.

They are placed for 9 panels, 10 ft. 8 in. apart, while the first panel on either side of centre post is 7 ft. 6 in. long. The centre post over pivot is a single one for each truss, and is compounded from four 6-in channel bars and 4 segments of a cylinder, riveted together by means of their flanges.

The diagonals are square bars, with upset screw ends bearing against angle blocks, fitting between shoulder plates riveted to under side of lower chord.

The cross girders at every other panel are single-trussed beams instead of double, as in the case of the fixed spans. The base castings of the end posts have a circular track bolted to them, composed of two 6-in channel bars, back to back. The bearing is upon wheels bolted to the masonry, and upon which the above track runs as the draw is open or shut. A self-acting, vertical latch secures the draw in position when closed for traffic, and is opened by means of a lever, operated at centre of bridge. A compound gear is arranged on the drum in case a heavy wind is blowing, or to ease the bridge tender in starting the bridge from its bearings after a long period of quiescence.

The following data in regard to "weights" will prove of value in this connection :

First.—Permanent span.

Average weight of iron per foot	620 lbs.	
Average weight of timber railing	710 "	
		1,330 lbs.

Second.—Draw span.

Average weight of iron per foot	1028 lbs.	
Average weight of timber railing	575 "	
		1,603 lbs.
Turn-table and appliances	85,000 "	

In the presence of the city authorities and parties interested in this work, a careful test was made by means of pig iron, with which the bridge was loaded up to one ton to the foot. Under this load the permanent spans deflected $\frac{7}{16}$ths of an inch, which was recovered when the load was removed. The draw was only loaded half its length, the result being a deflection of $\frac{9}{16}$ths of an inch, which was recovered before half the load had been removed.

Had the draw been loaded over its *whole* length instead of half its length, with a ton to the foot, the result would have been still more satisfactory. The deflection on either side would probably have been but little over half of what was exhibited. The result of these severe tests is regarded as eminently satisfactory. Although more attention has been given to æsthetical considerations than is usual in such work, much more could have been accomplished had the expenditure been authorized. As it stands, the bridge is painted a pleasing monotone of light yellow ochre, the effect of which would have been very much heightened by picking out the mouldings, bolt-heads, and other salient points, with an Indian or brownish red. This I trust will be done by the city authorities when the bridge requires re-painting.

It may be of interest to note the fact that *all* tension members in the main trusses were tested up to 20,000 lbs. per sq. in., which strain they were required to stand without a permanent set.

NAVIGATION OF THE GULF OF MANAAR.

From "The Engineer."

The success that has attended the efforts of M. De Lesseps to unite the waters of the Mediterranean and those of the Arabian Gulf, has had the effect of giving a stimulus to numerous undertakings similar in kind. Whatever geologists and geographers may think about the matter, engineers and capitalists are rapidly ariving at the conclusion that an isthmus has no business on the face of the earth, or on the map either. It is true that it may form the immediate link between continents or continents and their adjoining islands, but at the same time it constitutes an impassable barrier for ships proceeding to distant countries on either side of it. At the present day it is not sufficient to have two countries in connection, but they must be separated as well. The problem is solved by cutting through the isthmus in the first place, and bridging over the cutting in the second. A canal must run across the tongue of land to provide for the water traffic, and a bridge must be thrown over the canal for the transport of the land traffic. Thus native and foreign intercommunication will be established, and there will be at once a connection and a severance. That which has been accomplished on comparatively a small scale with our own railways and canals will have to be effected far more extensively, and with greater pretensions to magnitude, before some of the projects for severing the natural features of the globe arrive at a practical realization. The proposed piercing of the Isthmus of Darien is an old story, and from the last accounts not a whit nearer the desired stage than when it was originated. The discovery of the indispensable cañon, or gorge, through which the waters of the mingled oceans are to flow, is not the certainty that has been predicted, although it has been stated by some to be actually in existence. Similarly, the scheme for uniting the Archipelago with the Adriatic has not yet got beyond that preliminary state which, while it promises everything, accomplishes nothing. Were Venice still the emporium of Europe, were she still the Queen of the Adriatic, as she once was, there might be a hope that her interests would conduce to the severing of the Corinthian isthmus. But, as it is, the undertaking would not benefit—at least not for some time—the giant nations of the world. It would not connect two oceans, but simply a couple of inland seas, and it is questionable whether in the present state of Greece there is sufficient traffic to make the speculation remunerative.

But let the trade of the country be once developed, as it ultimately must

be, and the isthmus will be erased from the map.

Among other schemes of this character which have lain in abeyance for some years, but which appear to have been drawn forth from the apparent oblivion to which they were consigned by the event alluded to at the commencement of our article, is one which very materially affects our trade with India. It is nearly 9 years since the question was entertained by Parliament, and a committee appointed to inquire into the scheme of cutting through an island in the Gulf of Manaar, so as considerably to abridge the length of the voyage to Calcutta for deep-sea-going vessels. A glance at the geographical features of the proposed work will be of assistance in arriving at a clear comprehension of the value of it with respect to our oriental traffic. The main land of India, near its southern extremity, is severed from the shores of the adjoining island, Ceylon, by Palk Straits. In the narrowest part of the channel which intervenes between the Gulf of Manaar and Palk Straits there are one or two islands and a long shoal about midway, called by the ancient name of Adam's Bridge. This channel, which extends from Shoondradasy on the mainland to Mantotte in Ceylon, is navigable for vessels of a certain draught only, so that for others exceeding this amount it forms in reality an isthmus. The project has now been revived, and attention has again been drawn in Parliament to the necessity of piercing through the intervening promontory, and thus opening up a direct through route to the long stretch of the Coromandel coast and the Gulf of Bengal. It is estimated that the saving in distance alone for vessels bound to Calcutta would amount to 730 miles. In addition to this important advantage the place of call would be shifted from a situation where there is little or nothing in the way of refreshments for the crews and passengers of ships, to one which abounds in provisions of all descriptions, exceedingly well adapted for the consumption of voyages. It appears that, imperfect as the existing passage is, the ships which are able to navigate it have increased in numbers to such an extent that they now carry 200,000 tons instead of 7,000, which composed the whole of the traffic 40 years ago. This is quite sufficient to indicate that, were increased facilities for navigation afforded between Ceylon and the mainland, there would undoubtedly be a considerable augmentation in the annual tonnage of freight. The value of the new route would probably be enhanced in the course of time, when sailing vessels give place to steamers—a contingency that must happen sooner or later to all ocean-going ships.

When a project of the kind is mooted the first point to be settled is the party upon whom should devolve the construction of the work. In the present instance it has been broadly stated that the Indian Goverment ought to take the matter in hand, as the site of the proposed undertaking lies within their territory and jurisdiction, and moreover the result of the scheme would tend most unmistakably to the advantage of their dependencies. On the other hand, the Indian Government have many large and important works already in progress, which tax to the utmost their resources, and they in consequence do not feel themselves at liberty to commence others which are not so immediately connected with the country as those they are now engaged in. Is the work to be done by Government or by a company? As the former do not seem inclined to move in the matter, it may be presumed that if the work is done at all, it must be by the same means by which so many great engineering projects have been carried out, namely by private enterprise. Assuming this to be the case, the next consideration is, what will it cost and what return is it likely to yield on the capital expended? As to the prospective benefit that the opening of the channel will confer upon European or Indian traffic, that is a matter which in the abstract does not concern a company. Their only inducement to undertake the execution of the work is the probability of its eventually proving a remunerative concern. The cost of the entire work has been estimated at about £90,000; let us put it at £100,000. This sum is a mere trifle when weighed in the balance with the expenditure upon some of our home contracts. We are so accustomed now to deal in millions that anything below 1,000,000 is thought nothing of. There could not be the slightest difficulty in raising so small an

amount provided capitalists were tolerably certain of the financial success of the speculation. How then is the paying part of the undertaking to be provided for? In a manner similar to that which insures an annual revenue to the proprietors of the Suez Canal. All ships drawing more than a certain draught of water, which are now compelled to circumnavigate the island of Ceylon, would, in the event of the new route being opened, be able to pass through the channel and thus save over 700 miles in their voyage to and from Calcutta and other places situated in the Gulf of Bengal. For this considerable reduction in the length of their voyage they would be willing to make some return in the shape of a toll, and there is very little reason to doubt that, considering the comparatively insignificant amount of the capital required, the whole of the tolls would suffice to pay a very handsome profit. Experience has invariably shown that increased facility for traffic, whether of goods or passengers, is always attended with a commensurate increase in the traffic itself. They mutually act and react upon one another. The deep water channel cut through Adam's Bridge would very much exceed in lateral dimensions the Suez Canal. Indeed, it is now well known that it is only a question of time and money when the latter is to be both deepened and widened. The first great object to be accomplished was to prove that a navigable canal could be cut from one shore to the other. That being now satisfactorily demonstrated, the affair can be taken in hand and completed in the manner so great a work fully deserves. No means should be spared, whether the agent is the Government or a company, to reduce to a minimum the length of the voyage from our shores to those of India. The piercing of the Isthmus of Suez is the first step, and the cutting through of Adam's Bridge ought to be the second.

BROKEN TYRES.

From "The Mechanics' Magazine."

Next to fires, the easiest forms of disaster to classify are railway accidents, certain seasons almost invariably bringing particular descriptions of misfortune. The excursion season has its set, foggy weather is responsible for a share, and last but not least, severely frosty weather adds no inconsiderable quota to the list for any given year. Men of science, be they doctors or engineers, differ in their views, and it is only of late years that the members of the latter profession are becoming at all unanimous on the subject of the influence for evil exerted by hard frost on railway tyres. The arguments of those who denied the practical effect of any but extreme temperatures were based on the fact that iron had its tensile strength but little affected by ordinary winter frost in this country, so far as special experiments with testing machines were concerned. Facts, however, are stubborn things, and it is vain to say that frost cannot be the cause so long as tyres and axles break more frequently in cold than in warm weather. A little investigation, too, will go to show that experiment and practice, in the real sense of the terms, do not materially differ in results. It is one thing to suspend a bar of iron with a given load attached thereto, the thermometer recording so many degrees of frost, and quite another to set a railway wheel in rapid motion over a rail. In fact, the whole nature of the relative conditions are essentially different. To begin with, the strain of the tyre from tension is almost unknown in magnitude. No two tyres are shrunk on with the same amount of tension; no two are precisely alike in their chemical constituents. Again, a large allowance must be made for the influence of a frosty road; the metals during a severe frost have no particle of elasticity, and here is a source of fracture. To gain an idea of the different aspects of the question in frosty, and in summer or damp weather, we should suspend two rods and strike the one with an iron bar and the other with a bar of lancewood, or, better still, with a bar of whalebone. We find Russian and American engineers ready enough to acknowledge the effects of severe climates on their rolling stock, but really, when we come to examine the question, we find that it contains room for much

more investigation than it has yet received. For example, what do we know of the influence exercised by various forms of springs on the durability of tyres? To take a goods truck and a first class carriage would be but an imperfect comparison, because of the different nature and conditions of their work. One-half of its running time, a goods wagon wheel is loaded to its full amount, the rest of its time it is running comparatively idle; as a rule, too, its speeds are lower than those of the carriage. The single fact that the two vehicles afforded examples of the best and the worst forms of springs would not be enough. Another point again that might well be investigated is the influence exercised by different methods of construction of wheels on the durability of the tyres. Were we to have these sorts of accidents oftener, the influence of temperature would possibly be better examined into, and yet, even as it is, and setting aside the matter of life and limb safety, the question is one of interest from the abstractedly scientific point of view. Metallurgists well know that the presence of phosphorus in ever so minute a quantity will render iron cold short, so much so, indeed, that a smart blow will break a bar containing any without any question of fatigue of metal being involved at all. It is quite reasonable to suppose that, if a certain proportion of phosphorus render iron cold short where the difference of temperature lies between melting or welding point and ordinary weather temperature, a different proportion may have influence when the temperature is greatly reduced. That, however theorists may deny the influence of cold on wheel tyres or axles, railway companies are believers in it, we may gather from the fact that during severe weather the speed of fast trains is diminished. It is a pity that there is no published register of the lives of tyres and axles, with a statement of the methods of construction, the speeds, and the nature of the work each has been called upon to perform. Wheels which have wood interposed between the tyre and the axle ought to be more durable and less liable to fracture than those without an elastic medium between the two, yet we have no record of the relative number of broken tyres on the two types of wheel. Railway companies probably keep some such register to a certain extent for their own information, but we fancy it must be but an imperfect one. We wonder why the same plan of hooping railway wheels has not been adopted as that used for securing the rims of artillery wheels. There is no necessity whatever that railway wheel tyres should work in a constant state of tension. The duties of a tyre on a cart would consist in keeping the felloes together and on the spokes, but a rail tyre has not such duty to perform. In point of fact, the tread of the wheel should have no duty whatever to perform, but to take the wear of rolling on the rail and nothing else. Railway wheels, even to this day, are made too much on the principle of common wood wagon wheels, while the relative structures of the two types of wheel have nothing else in common. It may very reasonably be asked why is a railway wheel tyre shrunk on at all? Not to force the parts of the wheel together, as in the wood wheel; not to secure the tyre itself in its place, because it has no reliable effect of the kind. To what other purpose, then? To none but the evil one of putting the tyre in a constant fatiguing state of tension, injurious to the metal of the tyre, without any compensating beneficial effect. Many ways are to be found of constructing a wheel that will sustain a load without any hoop, and on this a hoop could be so secured as to form, not a circular girder, but simply a wear and tear band, which could be removed without difficulty. Why should not a wheel with rim, spokes and flanch complete, be forged in one solid piece, and afterwards a thin steel hoop be placed on the tread of the wheel, and secured with a few rivets; this could be taken off when worn and a fresh one put on; this, too, could be effected without the cost of turning the tyres on the wheels in the lathe, as they could be turned and bored true, and the wheels being turned true also when first made, the rim could be put on and riveted. Even did this outer hoop give way, there would be little chance of the train getting off the rails, as the wheel itself with its flange would be capable of bringing the train in safety to a station. The great evil of engineering is the proneness of its disciples to travel in a groove—to copy, or to adopt old cloth to the new garment. It is true that experiments are inadmissible where human life is concerned, but

experiments can be carried out with goods rolling stock at first, and afterwards with passenger carriages. From the pecuniary aspect, the question is worth dealing with, on account of the heavy bills for compensation paid by companies. There is one point that might perhaps prove objectionable to the thin tyre plan. The rolling action on the rail tends to stretch the tyre, and thereby enlarge its diameter, and thus loosen the hoop, but the question could alone be determined by actual experiment.

The use of wood in wheel construction has increased of late years, and few fast trains are made up now with any other style of wheel. Indeed, the idea of hooping a rigid iron wheel which is called on to endure much hard work of a concussive nature, with a band shrunk on, appears rather an unscientific proceeding. Tyres fail both from the fatigue of constant tension and concussion, and also from the strains caused by difference of speed between the two wheels on one axle in passing round sharp curves. Any means whereby loss of life and property from broken tyres is prevented is well worth the cost of a few experiments, and the increased immunity from accident and its attendant expenses would well repay the first outlay.

PURIFICATION OF PIG IRON.

From "Engineering."

There is one great and all-important problem which stands out prominently before the mind of every modern metallurgist as the next grand step to be taken in the practical manufacture of iron and steel—a problem, which in spite of all the power that has been brought to bear upon it during the last 10 years of gradual and extensive progress remains at the present moment unchanged in its stubborn resistance to science and skill, unsolved and apparently unapproachable by any of the appliances with which science has as yet furnished the practical metallurgist of the present day. The chemical differences between the highest classes of iron selected for the production of the best steel and the commonest brands of pigs, which are known in the market, consist in minute proportions of sulphur, phosphorus, and silicon, which are held in combination by inferior iron, while the absence of these elements is the characteristic of the high class material. The removal of these minute doses of foreign matter would have the effect, therefore, of abolishing all differences in quality, and consequently in value of the different brands of iron which are now collected from all parts of the world for the purpose of supplying the varied demands of iron and steel manufacturers; while, the quality of iron and its products being improved, there would result an extraordinary benefit to the iron industry at large. It is obvious, however, that all that can be gained by a successful process for purifying pig iron is to bring up the value of the inferior qualities of pig iron to that commanded by the pigs of superior purity; and therefore a process, in order to be practically useful, must not exceed in its cost the average difference which exists in the market between the prices of the highest class and the commoner classes of pig iron. This important point has proved the stumbling-block for several more or less ingenious inventors, who by their failures have pointed out more clearly than was before visible in what direction the road to progress did *not* lie. The removal of sulphur, phosphorus, and silicon from iron may be attempted in three different stages of manufacture, viz., the treatment of the iron ore, the refining of pig iron, and the process of manufacturing malleable iron or steel. The chronological order in which such attempts have been principally made follows the inverted course from that indicated above. The first efforts to purify iron were entirely confined to the process of conversion into malleable iron, and they have been so far successful as to master the difficulty in a more practical manner than any of the subsequent inventions have done. The silicon is entirely disposed of by the charcoal finery, and nearly so by the puddling process; a proportion of sulphur, and particularly a considerable proportion of phosphorus, are eliminated in the process of puddling and balling. With this,

however, ends the record of success as yet obtained in that direction. The action of the puddling furnace seemed to require some further assistance or stimulant for the removal of the noxious element, and consequently an innumerable host of ingredients have been proposed and tried in succession for effecting this desired end. Only a few of these attempts have had a sufficiency of scientific plausibility to deserve notice, but even these have not maintained themselves in practice. The powder composed by Schafhanth, consisting of common salt and oxide of manganese, was one of the most popular compositions of the kind ; its action was supposed to be due to the chlorine and the sodium in a nascent state. Next came the litharge, or oxide of lead process, relying upon the affinity of lead for sulphur and phosphorus at a high temperature. After the invention of the Bessemer process, hydrogen, chlorine, and carburetted hydrogen were tried in succession and blown through the converter, but without any favorable result. The Heaton process effected the purification by means of nitrates, but it proved, however, too expensive for commercial work. Mr. Bessemer at one time expressed an opinion that the removal of some noxious elements might be effected in the converter if the decarburization could be so protracted as to give a sufficient time to the other elements to combine with the oxygen of the blast. With a view to produce this result, the employment of hydro-carbons, naphtha, charcoal powder, graphite, and other carbonaceous matter, was tried in the Bessemer process, but no good resulted from all these experiments. M. Berard proposed to use the carburizing influence of a flame overcharged with gas in a Siemens furnace, for the purpose of keeping his bath of pig iron under the action of his process for a protracted period ; but M. Berard did not succeed in practically working out his ideas.

Inventors next turned to the refining process as a preliminary for the manufacture of malleable iron and attacked the impurities in that stage of the process of manufacture. Mr. Palmer Budd runs his pig iron over beds composed of oxide of iron and of nitrates ; M. Ellershausen mixes the pig and the oxide of iron into the form of sandwich cakes ; but from all this applied ingenuity there has resulted nothing of value for metallurgical practice.

At the present moment, two inventions for purifying iron ore are prominently before the public, and awaiting their trial in practice. The one is the process of Mr. J. E. Sherman, of which some accounts have already appeared in our columns, but upon which the evidence is not as yet completed. It has in its favor some decidedly important results, vouched for by the firm of the Atlas Works, and therefore readily accepted as facts, but it has against it the contradiction in which it stands to all accepted theory and chemical knowledge. A rival invention to that of Mr. Sherman is that of Mr. James Henderson of New York. This latter consists in the simultaneous application of fluorine and oxygen, and it has, at least, no theoretical improbability upon the face of it. Mr. Henderson employs fluor spar mixed with titaniferous iron ore, or with oxide of iron, either in the refining process, or in the puddling or steel-melting furnace. The effect of fluor spar upon pig iron containing phosphorus was tried repeatedly before this, but the result was negative. It does not from this follow that the effect of a combination of fluor spar with titaniferous iron ore, or with oxide of iron, will be equally ineffective, and it appears at least worth a trial, whether the process proposed by Mr. James Henderson has the germs of a final practical success in it or not. Both fluor spar and titaniferous iron ore are sufficiently cheap and abundant to permit of their being freely used for such a purpose, and the results if obtained by so simple a process, would be well worth trying for in this country at the present moment.

A new steam dredge has been launched from the foundry of Messrs. V. & D. Coates, Belfast. It is one of the finest in the country, and will be used in clearing the harbor and lough. It is of iron, 120 ft. in length, 24 ft. beam, worked by one pair of horizontal condensing engines; has 35 buckets, each capable of lifting 8 cwt. of sand.

The Brooklyn Pier of the East River Bridge will soon appear above the surrounding buildings.

FERRIE'S BLAST FURNACE.

From "The Scotsman," Scotland.

The following is a description of Mr. William Ferrie's blast furnace, which, 4 months ago, was lit up at the Monkland Iron-Works, Calderbank, near Glasgow. The furnace, we learn, is constructed on the bell and cone principle, neither flame nor smoke being allowed to escape at the top of the furnace. The coal is self-coked in 4 descending compartments or retorts, and the heat necessary for this purpose is created by the burning of the waste gases in a series of flues arranged around the retorts. In addition to an ample supply of gas obtained by the destruction of coal during the process of reduction and employed for the self-coking of the coal, an enormous surplus is given off, and, as we shall see by and by, is utilized in other departments of the work. Not only is there a sufficiency of gas to sustain a temperature ranging from 1,400 deg. to 1,700 deg. Fahr. in the flues, but a capacious pipe leads off a surplus to a distance of several hundred feet. From this main pipe gas is withdrawn to supply the heaters of other three furnaces, and this, too, in addition to supplying the heaters connected with the patent furnace, maintaining a heat higher and more regular than could ever be obtained by the employment of dross. This gas leaves the furnace at such a temperature as to render it highly and easily combustible. As to tar and other effete material supposed to be created during the operation of this furnace, it has been found not to exist. It is only in the situation of the valves connected with the main pipe, where the permeating gas comes incidentally in contact with the atmosphere, and becomes condensed, that any appearance of tar is found to exist, and then only to a trifling extent. This can easily be accounted for, from the fact that the gas is driven off in such a state of dryness as to prevent all likelihood of this occurring, so that the tar is volatilized along with the other volatile constituents of the coal, the temperature at this point being about 500 deg. Fahr. What economic value is obtained from the Ferrie furnace? What are its advantages over the ordinarily constructed furnaces in use throughout Scotland? The ordinary hot blast furnace requires for the production of every ton of pig iron 50 cwt. of coal; whereas by this new process it is an ascertained fact that 34 to 36 cwt. of coal will produce a ton of rich No. 1 iron, thereby effecting a saving of 17 cwt. of coal on every ton of iron made, or equal to 4s. 6d. In addition to this saving in coal, it will be seen from the following table that there is also a saving of 3 cwt. in ores, or equal to 2s. 5d. on every ton of pig iron produced. Nor is this all; for although those two items are the primary points of importance in the patent, it is also an ascertained fact that the heating power of the gas derived from the patent furnace represents in value—by saving a former consumption of 22 tons 8 cwt. of dross in the 12 hours at 2s. per ton—£2 4s. 10d., or equal to 3s. on the ton of iron made by this furnace. Thus upon its producing capacity for the year it gives a saving in dross alone of £1,500. This is exclusive of cost for the removal of ashes, wages, etc., which is equal to other 3d. on the ton of iron, *or* £125 per annum. No doubt, in a range of 8 or 12 hot blast furnaces, the quantity of gas produced would be more than sufficient for the raising of steam and heating of blast, and that possibly for a time a portion might not be utilized; but its known value is calculated to suggest other means for its application, such as calcining ironstone, etc.; but in circumstances such as exist at the Monkland Works, where there is a very large malleable work in addition to the manufacture of pig iron, the surplus gas can be applied to nearly its full extent, and thus form in the malleable department alone a very important saving in fuel. The saving proved to be effected in one furnace constructed on this principle amounts in coal to 4s. 6d., in ores to 2s. 5d., in dross to 3s. 3d., or equal to 10s. 2d. on every ton of iron this furnace makes, being equal in 1 year on a production of 10,000 tons to a sum no less than £5,083 6s. 8d. The following table gives the data carefully taken in estimating the comparative advantages of the new over the old open top furnaces:—Table showing the comparative results of the patent furnace No. 6, with an ordinary 50 ft. open top furnace,

No. 7, of the best modern construction, dating respectively from January 21st to February 10th, 1871, inclusive, being a record of 42 shifts; the materials used are the same in both cases, with the additional advantage that in No. 7 the heaters are fired with the gas obtained from the patent furnace No. 6 thereby receiving a steady temperature of blast equal to melting zinc at the external opening of the nozzle of the tuyere.

MATERIALS USED.

No. 6, OR PATENT.

Coal.		Ores.		Limestone.	
Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
1,144	45	1,127	4	409	11

Materials used per ton.

Cwt.	Cwt.	Cwt.
36.1	35.5	12.9

Production of Pig Iron.

No. 1.		No. 3.		No. 4		Total.	
Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
489	0	189	16	35	16 =	634	12

No. 7, AN ORDINARY FURNACE.

Coal.		Ores.		Limestone.	
Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts
1,145	6	1,071	2	375	14

Materials used per ton.

Cwt.	Cwt.	Cwt.
52	38.5	13.5

Production of Pig Iron.

No. 1.		No. 3.		No. 4.		Total.	
Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.	Tons.	Cwts.
333	3	196	16	25	13 =	555	12

The facts brought out in the above table prove that destruction of ores takes place in the open top furnaces through the intensity of heat produced by the burning of the gas. This fact is known to exist in reverberatory furnaces, for part of the iron there passes off in a volatile condition. In the case of the blast, a similar occurrence is not to be wondered at, the temperature being sufficiently high to volatilize part of the crude materials during the process of reduction. It was at one time contended that the interior brickwork would never resist the action of the intense heat produced by the burning gas in the flues—where the temperature is fully equal to a heat competent to coke coal—and that the crossed arches in the interior of the furnace would give way, and the whole collapse. This has been proved an utter fallacy; the furnace is so constructed that the interior of the flues can be examined, as they have been from time to time, and up to the present date not the slightest change in the brick is apparent; and when we find brickwork similarly conditioned, such as in the lining of a blast furnace, from the boshes upward, lasting (as in the case of the lower part in the present furnace) for 14 years, there is not the slightest apprehenson as to the durability of the flue brickwork. Altogether, Mr. Ferrie's ingenious invention is, doubtless, destined to mark a new and important era in the manufacture of pig iron. A more prolonged series of testing will still more confirm the good results which are confidently anticipated of it. It is one of great interest to Scotch iron-masters. In Scotland alone, where the annual make of pig iron exceeds 1,000,000 tons, the saving effected in coal by his process amounts to 850,000 tons, representing in value £233,750 and in dross 400,000 tons, or equal in value to £40,000, exclusive of the estimated saving in ores also.

RAILWAY accidents are now frequent in France. In a collision at Feugeray Lagnon between two trains, one coming from Rennes and the other from Redon, 6 people were killed and 24 injured, and at Puteaux a goods train ran into a passenger train carrying wounded Germans, 19 out of 32 carriages being broken to pieces.

THE value of the telegraph wire exported from the United Kingdom in 1869, exceeded £1,000,000 in value, being the largest amount ever yet imported. The next highest amount was in 1859, when it was nearly £750,000 in value. The gross value of the telegraph wire shipped since 1855 has been nearly £5,000,000. Last year's returns are not yet published.

THE new steamer "Sarpedon," commanded by Captain Charles Butler, of Belfast, has made a run from Liverpool to Hong Kong, including stoppages at Port Said, Suez, and Singapore, under 48 days.

THE new Beton Coignet is to be employed in the interior of the cathedral.

CAST AND WROUGHT IRON IN COMBINATION.

From "The Engineer."

The desire to carry out in practice the principles of correct theory is one of the motives which should always actuate the engineer or architect in the preparation of his designs for any work of construction. What we wish to be understood to mean is, that on taking up the drawing of a girder, a roof, truss, or any similar professional design, the observer should be able to perceive almost at a glance that it displays an attention to scientific rules and a correct appreciation of theory on the part of the designer. But this desire, however laudable, of embodying theoretical principles in actual practice, must be kept within certain limits, and it is a knowledge and recognition of these limits that constitutes the really clever, able, professional man. There is a vast difference between drawing a girder upon paper, working out the strains upon it, and getting it built. There are two well-known instances where the endeavor to which we have alluded has signally failed. One of these occurred in the early examples of timber railway bridges in America, in the combination of the arch and the horizontal principle. It was argued, and, in a scientific point of view, correctly enough, that by making the arch take all the compressive, and the truss the tensile strains, there would result the maximum of economy in the utilization of the material. In other words, it was proposed to divide the duty of carrying the load between the arch and the truss, and so proportion their relative powers of resistance that they should each be equal to their respective tasks. With any material this precise adjustment would be impracticable, but the fallacy of the attempt was rendered the more glaring in the case of timber. Various modifications of this compound system were tried, but the passage of a heavy rolling load was fatal to them all. It is uncertain whether the arrangement would have been a complete success when the structures were loaded only statically, but the impact of a moving weight caused distortions of so serious a character, that an additional amount of bracing was necessarily introduced, which at once destroyed the economy of the design. Experience very shortly proved that the idea of apportioning the material in the two principal members of the structure—on the assumption that each would just do its work, neither more nor less—could not be entertained, and that safety required that each member should be constructed of sufficient strength to carry the whole load to which the bridge might be subjected. This conclusion being satisfactorily demonstrated, led to the abandonment of the combined system, and a return to designs of a simpler nature followed as a matter of course. A variety of trusses upon the horizontal principle succeeded to that which had proved a failure, and they in their turn are rapidly giving way to structures of iron.

Another endeavor to carry out rigidly in practice the dictates of true theory occurred shortly after the employment of cast iron for girders, beams, and for general building purposes at home. The first series of experiments, conducted with the view of ascertaining the nature and extent of the resistance of cast and wrought iron to the strains of compression and tension, established some important and, until then, unknown results. It was discovered that the former possessed remarkable strength when submitted to strains of a compressive character, while the latter was distinguished by a proportionately powerful resistance to those of a tensile nature. This result held out to experimentalists and theorists the seductive argument, that by employing the two materials in combination in beams, in which each one would be subjected solely to the strain it was best calculated to sustain, their relative advantages would be most happily secured. This was the origin of the trussed beam, which consists of an ordinary cast-iron girder supplied with a couple of wrought-iron tension rods meeting under the centre of the girder, and connected with its extremities. It was imagined that by this arrangement the perfection of economy and distribution of material would be obtained, as the top or upper flange of the beam would resist the whole of the compressive strain, and the tension rods would materially increase the strength of the bottom flange. In the

ordinary examples of cast-iron girders of the best proportions, the bottom flange has an area equal six times that of the top in order to compensate for the weakness of the metal when exposed to a tensile strain. Consequently, if wrought-iron rods could be added as auxiliaries to the girder, so as to increase the tensile resistance, a manifest economy in material would result. It remains to be seen if this addition can be made with real advantage to the strength of the beam. It must be borne in mind that the rules which govern the proportions of cast iron girders were derived from direct experiment, and, although consonant with the dictates of theory, are more or less of an empirical character. By commencing with a beam in which the top and bottom flanges were of equal sectional area, and by adding successive increments to the bottom flange, the result sought for was at last arrived at. It was not until the ratio of six or seven to one between the two flanges was reached that the upper one evinced any signs of yielding. The beams experimented upon failed, either by tearing through the bottom flange or the rib. Theory assigns that when a cast-iron girder yields to a breaking weight, the upper flange should be on the point of rupture by compression, while the lower is equally strained to the utmost by extension. Similarly in a trussed beam in which cast and wrought iron are supposed to act in concert, the former material should fracture by compression at the same time that the latter yields to the force of extension. In a word, the whole beam should "go" together, and not fail by the yielding of any particular one of its component parts. In the latter event there will clearly be an excess of strength in the part that remains intact. With respect to a trussed beam, the girder itself and the auxiliary rods should, by their united action, support the load, as they are neither of them strong enough, *per se*, to do the whole duty. If therefore, from any cause, this union of their respective powers should not be effected, a greater share of the load would fall upon one or the other than it is capable of sustaining, and the girder would fracture accordingly.

Owing to the difference in the extension and in the set of the two materials, this united action can never be satisfactorily insured, although an approximation to it may be obtained. Briefly, it is necessary to impart some degree of initial tension to the wrought iron tension rods, and the difficulty lies in proportioning the amount. If it be too low it will permit the cast iron to yield prematurely; and if, on the other hand, it be too high, the rods themselves will give way. Besides, a high initial strain upon the tension rods will produce a dangerous strain upon the cast iron; and it may be stated that it is simply impossible by any method of adjustment to cause the cast and wrought iron to be equally strained when the fracture of the girder takes place. The most advantageous ratio that can be arrived at, is that the cast iron shall yield when the strain upon the wrought equals about two-thirds of its ultimate powers of resistance—the section of the tension rods being comparatively small to that of the girder, it would appear more economical to have an excess of strength in them than in the beam—calculating upon this as the breaking weight, and bearing in mind that cast iron ought not to be loaded in practice with more than one-fourth of it, the strain upon the tension rods would equal only one-sixth of their ultimate strength, and yet wrought iron may be strained more severely with safety than cast. In the opinion of many engineers, cast-iron beams and girders ought not to be subjected in practice to a working load of more than one-sixth of the breaking weight, especially if there be any probability of their being acted upon by vibratory or concussive forces. This would reduce the working strain upon the wrought iron to one-ninth of its ultimate strength, and thus only one half of the material would be utilized. The real objection to these compound beams lies not so much in the circumstance, that it is impossible so to adjust the tension of the rods that the resistance of the cast and wrought iron shall be brought equally into play, as in the fact that they are not always to be relied on. A very little difference between the actual strain and that provided for by calculation is sufficient completely to alter their conditions of safety. It is not difficult to perceive that this element of danger exists in the girder itself by nature of its very construction. If, from any extraneous or other cause, the strain upon the tension rods

should be suddenly and seriously increased, it might induce a correspondingly heavy one upon the cast iron, and the beam might fracture at once in the abrupt manner castings always do.

Many years ago some experiments were made by Sir William Fairbairn upon the strength of trussed beams, and results obtained which were at that time regarded as rather curious. If one of Mr. Hodgkinson's girders, in its correct position, with the broad flange downwards, be trussed with a couple of tension rods, there is an increase of strength of about one-fourth. If the simple beam be placed with the broad flange uppermost, it will be reduced in strength to nearly a half of that of the simple beam in the correct position. But if we now truss the girder with its broad flange uppermost, the gain in strength is nearly three and a half times that of the simple beam in the same position, and three quarters of that of the trussed beam with the broad flange downwards. In other words, the girder which is placed in an incorrect position, and trussed with tension rods, is considerably stronger than a similarly trussed beam in the correct position. At first this appears somewhat paradoxical, but a little reflection will show that the results are quite in consonance with the rules laid down by Mr. Hodgkinson. To take the case where the beam is trussed with the broad flange, or that containing the greater section area downwards. In this instance the greater part of the material—viz., that in the bottom flange—is exposed to a tensile strain, and consequently the assistance of the wrought iron rods is not so much needed. But in the other case the larger flange is thrown into compression, thus increasing the resistance of the top part of the beam, while the deficiency in the strength of the lower flange, which would take place if the beam were untrussed, is compensated for by the high tensile strength of the wrought-iron tie-rods. Arguing solely, therefore, on the score of apparent gain in absolute strength, the method by which to obtain a cast-iron girder of maximum strength is to take one of Mr. Hodgkinson's best form of girders, turn it upside down, and truss it with a couple of stout wrought iron tension rods. That combinations of cast and wrought iron have been successfully effected in many engineering structures, every one is well aware of. There are numerous bridges still existing in which the compound system has been adopted, and there are some also which failed most completely. The principle, widely disseminated in the infancy of railway bridges, may be summed up in the words, "Make those parts of a bridge which are subjected to compressive strains, of cast iron, and those which undergo tensile ones of wrought iron." Unfortunately this maxim was carried out in many instances to the letter, regardless of all contingencies that might possibly affect the structure. It is not to be wondered at that failure was the result. Some designs are so simple and obvious in their nature that they may be safely left to the "rule of thumb," but there are others—among which may be included the system in question—which require the highest skill and care in order to insure the requisite degree of strength and security. The practical objections which obviously exist against the combination of cast and wrought iron do not prevail with the same force against combinations of cast iron and steel, a subject on which we may have more to say.

A large and distinguished party of officers, scientific men, and others, assembled at the proof butts in the Government marshes, Royal Arsenal, Woolwich, to witness a trial of the new pattern Moncrieff gun-carriage for the 7 in. breech-loading gun. Four rounds were fired with perfect success. Captain Moncrieff worked the elevator himself, and the recoil each time brought down the gun under cover to the loading position with great exactitude. The preliminary trials being now complete, the carriage will be removed to Shoeburyness for further experiments. The hydro-pneumatic principle of raising the gun will, it is thought, altogether supersede the counterpoise system, being not only much cheaper, but more simple and durable. The new gun-carriage for the 7 in. breech-loading gun is estimated to cost about £90, whereas the carriage manufactured on the original principle, for the same gun, is said to have involved an outlay of about £1000. So far, the trial of the new pattern Moncrieff gun-carriage has proved highly satisfactory.

LIGHT SEA CABLES.*

From "The Electric Telegraph and Railway Review."

The British Association, to which the civilized world looks eagerly for a record of all the advance and improvements in the numerous branches of arts and science, holds a proud position with grave responsibilities; also, as the leader of the armies of knowledge-seekers, even-handed justice is meted to the laborers in the mine of intellectual power—unworthy prejudices and the damaging influences of vested interests have no place in either her councils or rules. With these impressions of the importance and universal usefulness of the Association, I venture to ask the section to take a glance with me at the progress that has been made in ocean telegraphy, with a view to its further development. If any important branch of it has been neglected it may now be fairly discussed.

The problem of laying telegraph cables across the deep oceans of the world has been on all hands—since the Commission of Inquiry published their report in 1861—admitted to be essentially nautical in its character.

The difficulties to be overcome showed the necessity for nautical science to be consulted, not by any mere casual inquiry, but by learned and practical investigation. I fear it has not been the habit of learned societies to discuss purely nautical science, which is much to be regretted. The vast ocean field, to which the world is so much indebted, remains—in many respects—still unexplored. Gentlemen of the nautical profession do not sufficiently combine to discuss and promote thereby the honor and interests of their class as those of other professions do. Hence, no doubt, the serious mistakes that have been made in ocean telegraphy.

Von Humboldt introduced to the world some complicated theories about ocean philosophy, which has tended to perplex rather than impart practical instruction; and Captain Maury begins his very pleasing "Physical Geography of the Sea" by saying "there is a river in the ocean," but fails to show from whence it comes or to where it goes. The effect, however, was to fill the heads of gentlemen who undertook the responsibility of choosing the character of the first Atlantic Cable and laying it, with the idea that a river of unknown rapidity and dimensions must be provided against. A cable, they supposed, must be made of iron to sink rapidly in this fast-running "river," and many of their class were under the belief that even the iron cable would never reach the bottom of the Atlantic. Captain Maury, however, in later editions of his work admitted that this river was on the surface.

The laying of the 1857 cable proved there was much more in the problem of ocean telegraphy than philosophers had dreamt of. Therefore a grand scientific inquiry was instituted, a commission of eminent gentlemen was appointed, jointly by the Board of Trade and the Atlantic Telegraph Company. By this time it was clearly understood that the laying of a deep-sea telegraph cable must be intrusted to nautical skill; but, strange to say, not one member of the nautical profession had any place on the commission. It is true several nautical gentlemen were, after a fashion, examined on the subject, but they were merely witnesses, and of course had not the power to call others, or to put pertinent and practical questions, or had they any responsibility as members of the commission. This, it must be admitted, was a serious mistake, of which I at the time most strenuously complained to both the Board of Trade and Chairman of the Atlantic Company. For two years the eye of the world was on England laboring to solve the great problem of ocean telegraphy. A Blue Book, of 516 folio pages, was then presented to the world. All the practical knowledge, however imperfectly gained by the commission, unmistakably goes to prove the many advantages of a light telegraph cable for ocean purposes.

Capt. Dayman, R.N., in his practical evidence, clearly proved this to every candid inquirer—(see the Blue Book of 1861, page 181.) I regret there is not time here to make elaborate quotations. The selection and loss of the 1857 Atlantic cable, and all the subsequent consequences, arose from a vague idea that there

*From a paper read before the British Association by Capt. W. Rowett.

were dangerous currents in the Atlantic, but by what law of nature as to their course, their strength, or their depth, they were regulated, nothing whatever seems to have been known; nor were any experiments instituted to prove any kind of theory, though this could have been easily done in the English Channel. With no unkindly feeling do we now refer to it, only as a beacon pointing out danger, and as a help to a more perfect solution of the problem. If, as it was supposed, there were abrading movements of the sea at extreme depths, a heavy iron cable such as would lie undisturbed was truly indispensable. If, on the other hand, there was no abrading motion at such depths—that it was entirely a mistake—then a cable of iron, or one loaded with iron, was not at all necessary. On the contrary, the cable that was made of the lightest material, provided it was the strongest fibre, and it did not absolutely float, would in every respect be the best; such cable would lie light as a feather on the bed of the ocean, and in time of need, be easy to lift from its resting place. Its tensile strength would be used to overcome displacement only, and not to lift from the bottom a heavy load, as the iron cables were, and which had so severely tried the skill of everybody to lay it safely, and when laid, to bring it again to the surface.

We need not here dilate upon the strength and spacific gravity of the various kinds of hemp and other fibrous material, for they can be mixed as may be found desirable. But for the purpose of our present argument, we class them as one, in contradistinction to metallic productions. A properly made hempen telegraph cable could be recovered from any depth in the Atlantic by the most simple process, because of its light specific gravity coupled with great tensile strength. Its capability to lift greater lengths of submerged cable in proportion to its specific gravity is clear, I presume, to every one's mind. A familiar illustration, however, will make it unmistakable to the general reader, however unnecessary for professional gentlemen. Let us suppose a telegraph cable made of iron wire the size of the Atlantic Cable of 1857, to weigh in water 1 lb. to the fathom, there would be no difficulty in laying it in a depth of 40 fathoms, because its dead weight is of course only 40 lbs. When the ship is still, and, under all circumstances, it is easily controlled even by hand. But mark the contrast: when the same cable is being laid in 2,500 fathoms, then the dead weight, when the ship is still, is no longer 40 lbs., but is in proportion to the depth 2,500 lbs., which is about equal to the weight of the lower anchor of a 1,000 tons ship. The cable being only the size of a man's finger, I need not say the weight is far too great to be safely controlled under the various circumstances that might arise on being laid.

Nearly 7 years passed before capital could be obtained for making the second Atlantic Cable, the specific weight of which was then happily reduced by putting a large mixture of hemp with the wire. It is not my intention to refer especially to the exact dimensions of that cable, but to proceed with the illustration which shows the true principle of ocean cable philosophy. By the mixture of hemp with wire, the cable being the same size as the one we have taken as data, we have reduced its weight when submerged from 1 lb. to 12 oz. to the fathom. Thus, in a depth of 2,500 fathoms, the dead weight is reduced to 1,875 lbs. This is a decided step in the right direction; the specific gravity of the cable being so much reduced, it is easier controlled when being laid, still its weight is far too great and altogether unnecessary.

It contains also other elements of insuperable danger to the perfection of a deep-sea telegraph cable—to which I may presently refer. It is admitted now by all concerned in ocean telegraphy that light cables are the *sine quâ non* of all ocean cables. But where lies the limit to which the lightness may be carried? Are the cables that have been successfully laid so light specifically as true science would justify? I answer emphatically, no! If, for example, a cable the size of which we have been speaking—having the same displacement to overcome—occupying the same space on ship board, be made to take another step in the direction of light specific gravity, not by reducing it from 12 to 6 but to 1 oz. to the fathom, thus the dead weight submerged in a depth of 2,500 fathoms would be reduced from 1,875 lbs. to 156 lbs. Light as 156 lbs. may be considered, it will sink at the speed of over 2 miles an hour, and when made of

double hard strands of pure and simple hemp, whatever may be the kind, it can be made as solid and unstretchable in water as an iron cable of the same size. 14 miles of such cable would weigh submerged 780 lbs., which is not one-third the weight it would bear, and on the authority of the Commission to which I have referred, an iron cable will break with the weight of 3 miles of its own length.

Some years ago, I was honored by Government with a request to furnish an estimate for making and laying a deep-sea telegraph cable, and its accompaniments, which were of various kinds. One provision was, that in case the cable broke in the operation of laying it, a number of grapnels and some 12,000 fathoms of large rope were to be provided, with which to recover the cable if it were lost. In replying to this request, I called attention to Captain Dayman's well-known soundings in the deepest parts of the Atlantic, which he invariably took with a hemp line; how he obtained samples of the soft ooze bed of the ocean; how he failed at any time to discover any under-currents, for, as he states, the slack sounding line went directly down and coiled itself upon the lead. In proof of this, the coils getting entangled with the sinker, on one occasion 200 fathoms of the line were hauled up in one lump with the sinker. I explained to them that, as Captain Dayman proved, there was a perfectly quiet soft bed of ooze on which the cable would lie undisturbed; that there were no currents to interfere with its passage there; and that his sounding line was a fit illustration of the character of the cable that would take the best possible care of the electric conductor—the hemp line had only to be enlarged to the dimensions required by the properly chosen core in the centre, it would run out from the ship as gently and be under as perfect control as a common log line, however tempestuous the weather. If the use of a heavy cable was so unsafe as they seemed to imply, they admitted a light cable could take care of it. I would, therefore, strongly recommend them to adopt the most common-sense view of the case, and put the electric wire into the hemp cable, which would save also the cumbrous and complicated machinery used for paying out the heavy cable. This communication had the effect of changing the views of the Government, and they abandoned their project without adopting my recommendation, for they were powerless against parties otherwise interested.

We have still to speak of the advantages of the simple hempen telegraph cable in various points of view. The economy of its construction and its portability must be evident to every one at all conversant with such matters. It must be clear also that if a cable can be laid across oceans at vastly reduced cost and risk—and this is as certain as there is truth in science—the effect must be universally felt when messages which now cost 30s. will be reduced to 5s., and so telegraphy will be brought within the reach of the millions of every country. The pofits to be derived from this expansion of telegraphy we may confidently believe will be as large from the low as from the high rates of charge, to say nothing of the civilizing and commercial advantages gained to the world, besides adding largely to the industry of the laboring classes. Other advantages of importance are gained by the use of hempen cables. It is clear of the destructive iron which is always a danger to the electric condition of the cable as well as a dangerous weight, and every way much more expensive when iron forms any part af the cable. On the other hand, the hemp rope is not only a natural bed in which the electric core can lie, but the hemp holds a preserving solution, which for all practical purposes makes it indestructible—keeping the strength of the cable intact for any period of time. At the same time the pure and simple hemp cable becomes so hard when in contact with water, that it will bear its entire tensile strength without elongating over 3 per cent.

From the Darien Canal surveying expedition very important intelligence has been received. Captain Selfridge, the commander of the expedition, writes from Paye, that he has discovered a route for the canal, the summit of which is but 300 ft. above the ocean, and that the route begins near the mouth of the Atrato river. If Captain Selfridge is not deceived as to the feasibility of this route, his discovery will have a most important influence upon the world's commerce, and will solve the Darien problem.

THE INFLUENCE OF INTENSE COLD ON STEEL AND IRON.

From "Nature."

There has recently been a most interesting discussion at the Literary and Philosophical Society, Manchester, on the above subject, the result of which seems to be that we must at once give up the idea that such accidents as the one, for instance, near Hatfield, are due to anything beyond the control of the railway companies concerned.

The paper which gave rise to the discussion was by Mr. Brockbank, who detailed many experiments, and ended by stating his opinion that iron does become much weaker, both in its cast and wrought state, under the influence of low temperature; but Mr. Brockbank's paper was immediately followed by others by Sir W. Fairbairn, Dr. Joule, and Mr. Spence, which at once put an entirely new complexion on the matter.

As Dr. Joule's results are the most to the point, we may take them first. He says:

"As is usual in a severe frost, we have recently heard of many severe accidents consequent upon the fracture of the tires of the wheels of railway carriages. The common-sense explanation of these accidents is, that the ground being harder than usual, the metal with which it is brought into contact is more severely tried than in ordinary circumstances. In order apparently to excuse certain railway companies, a pretence has been set up that iron and steel become brittle at a low temperature. This pretence, although put forth in defiance, not only of all we know of the properties of materials, but also of the experience of every-day life, has yet obtained the credence of so many people that I thought it would be useful to make the following simple experiments:

"1. A freeezing mixture of salt and snow was placed on a table. Wires of steel and of iron were stretched so that a part of them was in contact with the freezing mixture, and another part out of it. In every case I tried, the wire broke outside of the mixture, showing that it was weaker at 50 deg. F. than at about 12 deg. F.

"2. I took 12 darning needles of good quality, 3 in. long, $\frac{1}{24}$ in. thick. The ends of these were placed against steel props, $2\frac{1}{8}$ in. asunder. In making an experiment, a wire was fastened to the middle of a needle, the other end being attached to a spring weighing machine. This was then pulled until the needle gave way. Six of the needles, taken at random, were tried at a temperature of 55 deg. F., and the remaining six in a freezing mixture which brought down their temperature to 12 deg. F. The results were as follows:

Warm Needles.		Cold Needles.	
64 oz.	broke	55 oz.	broke
65 "	"	64 "	"
55 "	"	72 "	"
62 "	"	60 "	bent
44 "	"	68 "	broke
60 "	bent	40 "	"
Average $58\frac{1}{3}$		Average $59\frac{5}{6}$	

I did not notice any perceptible difference in the perfection of elasticity in the two sets of needles. The result, as far as it goes, is in favor of the cold metal.

"3. The above are doubtless decisive of the question at issue. But as it might be alleged that the violence to which a railway wheel is subjected is more akin to a blow than a steady pull; and as, moreover, the pretended brittleness is attributed more to cast iron than any other description of the metal, I have made yet another kind of experiment. I got a quantity of cast-iron garden nails, $1\frac{1}{4}$ in. long and $\frac{1}{8}$ in. thick in the middle. These I weighed, and selected such as were nearly of the same weight. I then arranged matters so that by removing a prop I could cause the blunt edge of a steel chisel, weighted to 4 lbs. 2 oz., to fall from a given height upon the middle of the nail as it was supported from each end, $1\frac{1}{16}$ in. asunder. In order to secure the absolute fairness of the trials, the nails were taken at random, and an experiment with a cold nail was always alternated with one at the ordinary temperature. The nails to be cooled were placed in a mixture of salt and snow, from which they were removed and struck with the hammer in less than 5 seconds."

The collective results of the experiments, the details of which need not be given, was that 21 cold nails broke and 20 warm ones. Dr. Joule adds:

"The experiments of Lavoisier and La-

place, of Smeaton, of Dulong and Petit, and of Troughton, conspire in giving a less expansion by heat to steel than iron, especially if the former is in an untempered state. Such specimens of steel wire and of watch spring as I possess expand less than iron. But this, as Sir W. Fairbairn observed to me, would in certain limits have the effect of strengthening rather than of weakening an iron wheel with a tire of steel.

"The general conclusion is this: Frost does *not* make either iron (cast or wrought) or steel brittle, and that accidents arise from the neglect of the companies to submit wheels, axles, and all other parts of their rolling stock to a practical and sufficient test before using them."

Mr. Spence, in his experiments decided on having some lengths of cast iron made of a uniform thickness of ½ in. square, from the same metal and the same mould. He writes:

"Two of the four castings I got seemed to be good ones, and I got the surface taken off, and made them as regular a thickness as was practicable.

"I then fixed two knife-edged wedges upon the surface of a plank, at exactly 9 inches distance from each other, with an opening in the plank in the intervening space, the bar being laid across the wedges; a knife-edged hook was hung in the middle of the suspended piece of the bar; to the hook was hung a large scale on which to place weights.

"The bar was tried first at a temperature of 60 deg. F.; to find the breaking weight I placed 56 lbs. weights one after another on the scale, and when the ninth was put on the bar snapped. This was the only unsatisfactory experiment, as 14 or 28 lbs. might have done it, but I include it among the others. I now adopted another precaution, by placing the one end of the plank on a fixed point and the other end on to a screw-jack, by raising which I could, without any vibration, bring the weight to bear upon the bar. By this means, small weights up to 7 lbs. could be put on while hanging; but when these had to be taken off and a large weight put on, the scale was lowered to the rest, and again raised after the change was made. I may here state that a curious circumstance occurred twice, which seems to indicate that mere raising of the weight, without the slightest apparent vibration, was equal in effect to an additional weight. 3¾ cwts. were on the scale, a 14 lbs. weight was added, then 7 lbs., then 4 lbs., 2 lbs., 1 lb., and 1 lb., making 4 cwts. and 1 lb. This was allowed to act for from 1 to 2 minutes, and then lowered to take off the small weights, and replaced by a 56 lbs., intending to add small weights when suspended, raised so imperceptibly by the screw, that the only way of ascertaining that it was suspended, was by looking under the scale to see that it was clear of the rest. As soon as it was half an inch clear, it snapped, thus breaking at once with 1 lb. less than it resisted for nearly 2 minutes.

"Six experiments were carefully conducted at 60 deg. F., the parts of the bars being selected so as to give to each set of experiments similar portions of both bars; the results are marked on the pieces. My assistant now prepared a refrigerating mixture which stood at zero, and the bars were immersed for some time in this, and we prepared for the breaking trials to be made as quickly as could be, consistently with accuracy, and to secure the low temperature, each bar, on being placed in the machine, had its surface at top covered with the freezing mixture. The bars at zero broke with more regularity than at 60 deg., but instead of the results confirming the general impression as to cold rendering iron more brittle, they are calculated to substantiate an exactly opposite idea, namely, that reduction of temperature, *cæteris paribus*, increases the strength of cast iron. The only doubtful experiment of the whole twelve is the first, and as it stands much the highest, the probability is that it should be lower; yet, even taking it as it stands, the average of the six experiments at 60 F. gives 4 cwt. 4 lbs. as the breaking weight of the bar at that temperature, while the average of the six experiments at zero gives 4 cwt. 20 lbs. as the breaking weight of the bar at zero, being an increase of strength from the reduction of temperature equal to 3.5 per cent."

Sir W. Fairbairn's evidence is of great importance, for he not only gives facts showing that frost does not affect the tires, but he states the real cause of such accidents as are generally attributed to the frost. He states:

"It has been asserted in evidence given at the coroner's inquest on the Hatfield

accident, that the breaking of the steel tire was occasioned by the intensity of the frost, which is supposed to render the metal brittle, and of which this particular tire was composed. This is the opinion of most persons, but judging from my own experience, such is not the fact, and provided we are to depend on actual experiment, it would appear that temperature has little or nothing to do with it. Some years since, I endeavored to settle this question by a long and careful series of experiments on wrought iron, from which it was proved that the resistance to a tensile chain was as great at the temperature of zero as it was at 60 deg. or upwards, until it attained a scarcely visible red heat. To show that this was the case, and taking, for example, the experiments at 60 deg., it will be found that the mean breaking weight, in tons, per square inch, was in the ratio of 19.930 to 21.879, or as 1 : 1.098 in favor of the specimens broken at the temperature of zero. The generally received opinion is, however, against these facts, and it is roundly asserted that the strength of iron and steel is greatly reduced in strength at a temperature below freezing. The contrary was proved to be the case in wrought-iron plates, and assuming that steel follows the same law, it appears evident that we must look for some other cause than change of temperature for the late fracture of the tire on the wheel of the break-van of the Great Northern Railway. * * * * The immense number of purposes to which both iron and steel are applied, and the changes of temperature to which they are exposed, renders the inquiry not only interesting in a scientific point of view, but absolutely necessary to a knowledge of their security under the various influences of those changes; and when it is known that most of our metal constructions are exposed to a range of temperatures varying from the extreme cold of winter to the intense heat of summer, it is assuredly desirable to ascertain the effects produced by those causes on material from which we derive so many benefits, and on the security of which the safety of the public frequently depends. It was for these reasons that the experiments in question were undertaken, and the summary of results are sufficiently conclusive to show that changes of temperature are not always the cause of failure, as that which occurred near Hatfield on the Great Northern Railway. That such is the fact, I may adduce several accidents of broken tires, all of which occurred during the spring and summer months when the temperature was high. One of them occurred on the Lancashire and Yorkshire Railway in the summer of last year, when the temperature was 50 to 60 deg. above freezing. I could enumerate others in which the winter frosts had nothing to do with the fractures which ensued."

After referring to some other experiments, Sir W. Fairbairn proceeded:

"The danger arising from broken tires does not, according to my opinion, arise so much from changes of temperature as from the practice of heating them to a dull red heat and shrinking them on to the rim of the wheels. This, I believe, is the general practice, and the unequal, and in some cases, the severe strains to which they are subject, has a direct tendency to break the tires. To show how easily this may be effected, let us suppose that a tire 2 ft. 6 in. or 3 ft. diameter, is shrunk on to a wheel $\frac{1}{4}$ in. larger than the tire, it then follows that the tire in cooling must be elongated to that extent, with a strain equivalent to the force of the shrinkage, and calculated to produce that amount of molecular disturbance. It may be more or it may be less, but supposing the strain to be one-half or three-fourths of that which would break the tire, it then follows that the constant action of its irregular motion on the rails must ultimately lead to fracture. I am not surprised that this should be the case, as most if not the whole of railway tires, excepting those on engines and tenders, are not turned, but selected by hand, heated and shrunk upon the wheels with every degree of tension, as suits the convenience of the workman. So long as this process is pursued the public will be exposed to the risk of broken tires. What is required in this description of manufacture is, that the rim of the wheel and the inside of the tire should be turned to a standard gauge, accurately calculated to give the required amount of tightness with a larger margin of strength, and this done, we should attain greatly increased security to the public, and a great saving in wear and tear—to say nothing of the large sums expended by companies in the shape of compensation for injuries and loss of life."

Here, then, is another potential triumph for more scientific accuracy and more hope for travellers.

* * * * * *

Upon the above discussion, "Engineering" comments as follows:

As to the effect of cold on the tensile strength of steel and iron, we fully agree with the results of experiments, such as those made by M. Styffe and others, which show that the power of these materials to sustain dead weight is rather increased than diminished by cold; but it is difficult to establish any definite relation between tensile strength and resistance to concussion, and more particularly to the effect of numerous small vibrations.

There can be little doubt, moreover, that iron and steel are sensibly affected by changes of temperature, the more extreme these changes and the more suddenly they are brought about the greater being their influence on the strength of the materials exposed to them. The quality of iron, too, varies greatly, and as the variations in quality greatly modify the power of the material to resist particular kinds of strain, it is the duty of railway engineers to study both the mechanical properties and chemical composition of the iron employed by them, and to select those kinds best suited to the particular work they have to perform. Thus it has been shown that phosphorus, when present in iron, diminishes the resistance of that material to impact at low temperatures, although at the same temperatures it by no means exercises a similar influence on the resistance to steadily applied tensile strain; and thus we are led to the conclusion that such iron is unfitted for employment in situations in which it will be subjected to the combined influence of severe cold and concussion, although it may safely be employed in cases where, although exposed to cold, it is subjected to steady strains only. It should be remembered, however, that all railway plant is subjected to concusions of a more or less violent kind, while the greater the speed at which the traffic is carried on, and the less perfect the condition of the permanent way and rolling stock, the more severe such concussions are. Thus we find that in Russia the experience on the railways has proved decisively that the sharper concussions produced by an increase of speed result in an increased number of breakages.

As to the difference between wrought-iron and steel in resisting the influence of a cold climate, we think that there can be no doubt that a mild steel, containing no more than from $\frac{1}{3}$ to $\frac{1}{2}$ per cent. of carbon, decidedly deserves the preference. In fact, the results obtained by the extensive use of steel tires, axles, and rails, in cold climates, such as Canada, Russia, and Sweden, prove practically what might have been anticipated on theoretical grounds, namely, the advantages to be derived from the use of mild steel. We hope before long to have an opportunity of again speaking on this subject, but meanwhile we would direct attention to those countries which are less favored in respect to climate than our own for experience as to the influence of cold on iron and steel. For we must remember that while we in England have occasionally a winter like the present and that of 1862, with the thermometer down to 10 deg. Fahr., railway men in Russia, Sweden, and Canada, have very often, if not indeed every year, to deal with such temperatures as—30 deg. Fahr., and have yet to carry on their traffic with safety. We may, therefore, well take lessons from them, even while we congratulate ourselves on being placed under more favorable conditions.

In conclusion, we desire to say a few words as to methods of testing iron and steel. We much wish that as a general rule materials for railway plant were subjected to tests corresponding tolerably closely to the actual work which such materials have to perform, and, as nearly as possible, under similar circumstances. Iron and steel used in the construction of railway plant should be tested for hardness, homogeneity, and resistance to impact, and if the tensile strength be ascertained, the recorded results should also show the limit of elasticity and the elongation before fracture. For bridge-work, the materials should be tested for tensile strength, elongation, and resistance to impact, simultaneously, while for roofs or buildings subjected to statical strains, the tensile strength and the stiffness are perhaps the qualifications which it is most desirable to ascertain with accuracy. In addition to the mechanical tests, the chemical composition of the materials should be the object of careful investigation in order to ascertain the amounts of carbon, silicon, phosphorus, sulphur, etc., present;

and, lastly, the mechanical tests should be applied at temperatures similar to those to which the materials would be exposed in actual use. Were these precautions more generally observed, the right material would be used in the right place, and numerous failures of a disastrous and frequently costly kind would be avoided.

ZINC AND ITS MANUFACTURE.

From "The Mining Journal."

Apropos of the recent publication of certain statistics of the zinc manufacture, by M. Ed. Fuchs, and of the annual report (April, 1870) of the largest zinc-producing company in the world, we purpose to review in brief the history and position of the zinc trade. Although known as a substance whose mixture with copper produced brass, and though worked for this object from the 15th century, the ores of zinc failed to furnish the metal as a branch of industry until the 19th century. In England, so early as the 16th century, the metal was isolated by Paracelsus, but no further advance seems to have been made towards its economic application, until in 1805, after an extensive series of experiments to reduce the carbonate to the metallic state, a Belgian chemist, L'Abbe Dony, succeeded in obtaining the metal by sublimation. The rude apparatus in which Dony first accomplished the condensation of zinc has, with slight modifications, been largely employed ever since, under the name of the Belgian process. This apparatus was no other than a flower-pot, fixed in the side of his furnace, and having a hole pierced through, the better to observe the progress of the operation. In this recess the zinc deposited in little drops. The metallurgy of zinc was known. The flower-pot has been replaced by retorts, provided with movable horn-like prolongations, in which the metal collects; the number and size of the retorts have been gradually increased, but the process remains to this day substantially as Dony left it.

Simultaneously with Dony's invention at Liége, a similar process was discovered in Silesia. The sinkings for coal at Tarnowitz had disclosed vast beds of calamine, which, though inferior in point of purity to the Belgian ores, were of sufficient importance to create a new and flourishing industry. Here the reduction of the ore, previously pulverized and mixed with ground coal, was accomplished in a muffle, terminating in its upper extremity in a tube, which passed through an aperture in the side of the furnace, and, bending downwards siphon-wise, allowed the condensed metal to flow out. The siphon form has, however, been abandoned in favor of a series of double recesses, in which the zinc collects, and is removed by a descending pipe into cast-iron cups. A third method was practised for sometime in England, known as distillation *per descensum*, in which the ore was reduced in retorts or crucibles, arranged on the shelf of a furnace of the ordinary glass-house form. Through the bottom of each crucible a pipe descended to the cool cavity underneath. This opening in the bottom of the crucible was closed at the commencement of each operation by a wooden plug, which, becoming converted into charcoal by the heat, allowed the zinc vapor to percolate through its pores, and run down the tube into the receiving vessel. This system, though it is said to yield good results, is wasteful in fuel, and is now generally abandoned in favor of one of the processes before mentioned, or some modification of them.

The first zinc works was established at Liége, by Dony, in 1807. It was supplied with ore from the calamine beds of Moresnet, of which he had obtained the lease. But Dony paid the price of most inventors — he enriched the world and impoverished himself. Finding the demand for the new metal increase so slowly, and his resources gradually diminishing, he was at length obliged to sell the lease of his rich zinc mines, after having worked them for eight years. These deposits of zinciferous carbonate have since acquired a world-wide notoriety in the hands of the Vieille Montagne Company.

The mining of the ores of zinc is by no means of so recent date as its metal-

lurgy. So early as 1425, the annals of the Duchy of Limbourg mention the calamine explorations of Altenburg; and for a long time blende and carbonate of zinc have been mined, as secondary products, in Rammelsberg and other parts of the Hartz Mountains. The chief ores for industrial purposes are blende, a protosulphuret, and calamine, a carbonate of zinc, having very frequently an admixture of silicate. Though theoretically richer in metal than the carbonate, blende is more difficult in its treatment, and yields a less percentage to the manufacturer. The carbonate occurs both in veins and beds, in the Devonian measures of Ardennes, the Hartz Mountains, and the Erzgebirge, and among the limestones of Derbyshire and Cumberland, and in the transitional rocks of Hungary and Silesia. It sometimes forms the lining on the cheeks of lead veins, and sometimes is associated with the galena, in which case it is never very dependable, its continuance being often abruptly supplanted by blende, galena, or pyrites. This is especially the case in the zinc mines of Spain, and in the newly-opened workings in Sardinia. Blende occurs chiefly as an alternative in lead mines, and sometimes in copper and other metalliferous veins, but it is occasionally found in masses, like the Cornish "floors," or the German "stockwerk," as in the rich mines of Iglesias, in Sardinia, and of Stollberget and Ammeberg, in Sweden. About half of the zinc ores of Europe is supplied by Prussia. In Silesia there are 30 mines in operation, partly worked by shafts and partly by levels driven into the hills. They employ 15,000 workmen, and yield annually 221,000 tons of calamine. In Westphalia, 70,000 tons are supplied from 75 works. The Rhine ores consist of blende, largely mixed with lead and iron. In some parts the iron reaches 18 per cent. of the calcined ore, but no effort has yet been made towards its utilization. Here 6,000 men are employed. Belgium, the oldest zinc-producing district, supplies 57,000 tons, Poland 12,000 tons, and Spain 50,000 tons. These ores are chiefly the carbonate, containing portions of blende and galena. France contributes 3,000 tons, and Ammeberg, Sweden, 12,000 tons. The sulphuret from these Swedish mines is very pure, and admits of tolerably easy reduction. From Iglesias 20,000 tons come. This district in Sardinia has but recently become a producer of calamine. In 1866 the total quantity raised was 13,000 tons; increased in 1869 to the amount given above. Immense stores of calamine enrich Sardinia, and the supply seems to be only limited by the difficulties of transport, which, it is said, will prevent the annual yield from exceeding 40,000 tons. These Sardinian deposits are regarded as the only carbonates at all comparable, in point of purity, to the far-famed calamine beds of Moresnet and Tarnowitz. America produces about 12,000 tons; but the disorganization of the civil war interrupted the annual reports after 1863, until recently. In Italy and other countries, including England and Algeria, where, at the present moment, a Belgian company is preparing to open out a zinc mine, 12,000 tons are raised.

In the metallurgy of zinc, the first point to be accomplished is its slow and uniform roasting. This is effected at present in a furnace, whose sole is divided into two or three compartments, of varying heats, and the ore is drawn from the first to the next, at intervals of about eight hours, in such manner that the mineral is first gently heated, and gradually increased to the utmost power of the furnace. A self-acting machine has been invented by M. Gerstenhöfer, to avoid the immense hand labor involved in this operation. This apparatus is used in England and Belgium to some extent, but does not seem to fulfil all the desirable conditions, and the ore calcined is neither so uniformly nor so thoroughly roasted as by the hand method. From the calcination the ore is carefully ground, and mixed with coal dust. Coke dust is used in Silesia, to avoid the stoppage of the pipe that delivers the zinc from the muffle, by the adhesion of the tarry matters of raw coal. Here very little labor is required from the workmen; the zinc continues to condense and flow down the siphon to the end of the operation. In the Belgian process, however, when the ore has been placed in the retorts, and has begun to sublime, the horn-like prolongations are taken off every two hours, and carefully emptied into the receiver. The fact that this method requires a lower temperature than the Silesian process, has been utilized in arranging some Belgian retorts

above the ordinary Silesian furnace. This method has been established at the zinc works of Valentin Cocq, with a considerable economy of fuel. The cost of the Belgian and Silesian processes is about equal, the first having an advantage in fuel, and the second in hand labor, and in the longer endurance of the furnace. The points to which attention is directed to reduce the cost of zinc production are, to augment the yield by increasing the size and number of the retorts, and to reduce the amount of fuel consumed. In the Belgian furnace it is customary to arrange 70 retorts, and from 30 to 40 in the Silesian, the daily yield amounting respectively to 11 cwt. and 20 cwt. The fuel required in the Silesian furnace is 2½ tons of coal per ton of ore. Three-fourths of the metal contained in the ore is by these means extracted. With the object of still further reducing the expenditure of fuel, which in Prussia and Belgium is more costly than with us, various forms of grate have been tried for the reducing furnaces, with but partial success. An English patent taken out some two or three years ago, by Messrs. Tildesley & Bird, seems to us most likely to answer the purpose. Furnace grates, similar to Siemens', are used with moderate success in France and Silesia.

The metallurgy of zinc, like its mining, is confined to a few centres. In England, the principal works are Messrs. Vivian's, at Swansea, and these depend partly on foreign supplies of ore. The entire produce of Europe is 120,000 tons; of this Prussia contributes 80,000. The largest of the Prussian works is the Silesian Society of Mines and Foundries, which keeps in activity no less than 150 furnaces, and turns out annually 8,000 tons of raw zinc, and the same quantity of sheets. The cost of the reducing operations at these works is 11s. 10d. per cwt. of zinc produced; and the selling price at the market town, some miles distant, has been for the average of the last few years 22s. 4d. per cwt. The extra cost for rolling is 1s. 3d. per cwt. of sheets. This price is slightly augmented in the case of the thinner varieties. The largest zinc works in the world is La Vieille Montagne, near Liége. Last year this company raised 68,379 tons of ore, and in their own two collieries 89,452 tons of coal, while the total manufacture of zinc attained the amount of 44,441 tons, of which 35,213 consisted of sheets, 5,965 of zinc-white, and the rest of various castings—ingots, wire, nails, ornaments, etc. The entire sales of this company last year, according to the official report of April 30, 1870, amounted to the sum of £1,000,000, being 30 per cent. of the entire produce of Europe, and resulting in a gross profit of £212,557, which allowed a dividend to be declared of 25 per cent. on the capital. At these works sheet-zinc is rolled to any thickness. The plates are rolled at a temperature of about 212 deg., which heat is generally developed by the pressure of the process. The specific gravity is thereby increased from 6.8 to 7.2.

Two-thirds of the total quantity of zinc produced is manufactured into sheets, the remaining one-third is employed for brass-making, for wire, for zinc-white, as a substitute for lead in paints, and for castings, which last, by the way, are made in moulds of iron instead of sand, thereby attaining a cleanness and finish before unknown, besides considerably reducing the expense of manufacture. That the consumption of zinc is far from having attained its normal development may be seen from the fact that while France consumes 35,000 tons annually, and Great Britain and her colonies 30,000, and Belgium 6,500, Germany uses but 22,000, Italy, Russia, Spain, and other countries together only 10,000 tons. The two chief requirements for zinc sheets are roofing and sheathing the bottoms of ships, the usual thicknesses for roofing purposes being from .028 in. to. 044 in., while for ships' bottoms they vary from .038 in. to .048 in. Mr. Daft, an English engineer, has recently proposed an ingenious application of zinc sheeting to iron ships, whose chief advantage seems to be the avoidance of vegetable and animal growths on the bottoms of vessels by means of the galvanic current set up between the two metals when in the presence of salt water.

The inventor of the Bavarian "mitrailleuse" received $4,000 for the invention, and he gets an additional sum of $120 as royalty on every mitrailleuse which leaves the Government manufactory.

THE COMPOUND STEAM ENGINE.

At a recent meeting of the New York Society of Practical Engineering, Mr. Charles E. Emery gave the following brief statement of his views concerning the advantages of the compound steam engine as compared with the ordinary double-acting engine.

1. It furnishes a better working engine, mechanically, for utilizing the benefit of the expansion of high pressure steam.

This point will be very generally conceded. The expansion of steam is necessary to secure economy; but if the application of the principle be carried to the extent desired, the great changes of pressure in the cylinder cause severe strains on the main connection, and although the latter be made unusually strong, it is frequently found expedient to reduce the pressure, and necessarily the measure of expansion, and so increase the consumption of fuel, in order to reduce the losses caused by frequent repairs, but more particularly by the delays they occasion. The compound engine, in any form, equalizes the strains and distributes the load.

2. Independently of mechanical considerations, it is more economical to use steam expansively in a compound engine than in any form of the ordinary engine.

This point must be accepted as a fact by any one who will examine the evidence available, but the abstract explanation of the result is impossible by any of the laws heretofore laid down in respect to the steam engine.

It should be borne in mind that, contrary to the opinions of many, there is no gain in power by the addition of the small high-pressure cylinder of the compound engine, for the effective pressure upon its piston is only the difference between that of the entering steam and that admitted to the second cylinder. There is, in fact, a little power *lost* in transferring the steam from one cylinder to the other. It is not strange, then, that nearly all American engines condemn the compound engine and declare, in spite of all failures, that the same result can be produced in a single engine if it be made of sufficient strength to withstand the unequal steam. These engineers simply judge from the information they have had the opportunity of acquiring. They have been taught that the capacity of the cylinder is the measure of the steam used, and reason that if the compound engine gives no more power with the same steam, it is a useless contrivance. No other conclusion could be based on such an assumption. The error in the reasoning lies in the fact that the volume of the cylinder is not an accurate measure of the quantity of steam used by the engine. This fact has been proved by experiment, both at home and abroad, but, strange to say, has never attracted much attention. People will assume that steam *can* be measured by the cylinder fully as accurately as peas in a bushel; but the fact is, that the metal walls of a steam cylinder are at every stroke so cooled by the performance of work, and by the low temperature during the exhaust, that the live steam, upon entering, has two offices to perform, viz.: 1st, to reheat the surfaces, and 2d, to fill the cylinder and maintain the desired pressure. In many cases it may require as much steam to do the first as the last; and as the steam for the first purpose is condensed, that for the second will only fill the space; and, in fact, two volumes of steam may enter a vessel capable of holding but one of a liquid or non-condensable gas.

During the Government expansion experiments, and others of a private character, I had ample opportunity to ascertain the accuracy of the above views, and found that the benefits to be derived from expansion were, in the manner stated, greatly reduced, though not entirely overcome, as had in some cases been claimed.

I believe these losses could be prevented, and, with means furnished by capitalists, have tried over 250 experiments to ascertain the value of the various devices for accomplishing this end. The nature of the loss was proved in the following manner: "I constructed two cylinders of like dimensions, one of glass, the other of iron, in such a manner that either could be attached to a valve which regularly admitted steam from a boiler to the cylinder and permitted its exhaust into a condensing coil lying in a tub of water." The capacity of the two cylinders was

made the same, as was shown by transferring water from one to the other. When put in turn in condition of a steam-engine cylinder, the iron cylinder used (averaging the experiments) fully twice as much steam as the glass one, shown by the fact that twice the quantity of water came through the condensing coil for the same number of movements of the valve. Steam of the same pressure was used in both cylinders, and the experiments were many times repeated, with substantially the same results. This settles the question. The glass cylinder saved half the steam. The cylinder of a perfect engine should, then, be made of glass or other non-conducting material, which may be explained in the following manner: Tyndall has found that aqueous vapor is one of the most powerful radiators and absorbents of radient heat known. Steam, when slightly chilled by the performance of work, is in respect to heat in the same condition as the aqueous vapor of the atmosphere; therefore, if steam enters a cylinder at, say, a temperature of 280 deg., and heats the metal surfaces to that point, when such steam is exhausted and falls in pressure so that the temperature is only, say, 130 deg., the surfaces rapidly radiate heat, which is absorbed by the steam and carried to waste; and the next steam that enters has to re-heat the surfaces, and an additional quantity is required to fill the cylinder and do the work. A non-conducting cylinder does not become cooled, and only the exact quantity enters which is required to fill it.

I experimented considerably to make an engine with a cylinder of non-conducting material, and only desisted, temporarily, when it occurred to me, and I proved by experiment, that nearly the same result could be obtained by the use of a modification of the compound engine which involved no difficult mechanical details.

The transfer of heat from the metal walls of the cylinder to the exhausting steam takes place in two ways, viz.: by direct contact and by radiation. The bulk of the steam can only be acted upon by radiation, which therefore causes the material part of the loss.

It has been proved by experiment that the quantity of heat transferred from a radiating to an absorbing body varies as the square of the difference of temperature of the metal surfaces; so, taking the previous case, viz.: that the temperature of the metal surfaces of a steam cylinder is 280 deg., and that of the exhaust steam 130 deg., the difference in temperature is 150 deg.; and, if we use the steam in two cylinders instead of one, we may reduce the temperature in each to, say, $\frac{1}{2}$ that amount, and the condensation will be 1^2 to 2^2, or $\frac{1}{4}$ as much in the two cylinders as in the single one, or not less than $\frac{1}{3}$ as much, if an allowance be made for the increased surface in the two.

This explanation shows that if the condensation in the single cylinder be $\frac{1}{2}$ the whole amount, that $\frac{2}{3}$ of this, or $(\frac{2}{3} \times \frac{1}{2})$ *one-third* of the whole may be saved by the compound engine, which calculation agrees with the facts, but varies, of course, with the changes in the conditions.

The explanation once obtained, it enables one who has studied the subject to proportion the compound engine so as to obtain the maximum efficiency. I have known many of them that were so constructed that they gave but little better results than a single engine. In addition to the above, it is well to state that during the experiments several improvements applicable to the compound engine were worked out, which, in connection with the principle, using a steam pressure of only 40 lbs., reduced the cost of power in the experimental engine from 39.2 lbs. of feed water per horse-power per hour to 23.6 lbs. This proportion of saving would, in a larger engine, reduce the cost to as nearly that promised in my theory as the most sanguine could expect, for large engines are positively known to be more economical than small ones, which may be explained by the fact that the ratio of internal surface to capacity decreases with the size of the cylinder.

Further details would make this communication too lengthy. I should be happy to furnish you with a more elaborate discussion of the subject if desired. The practical evidences of the advantages of the compound engine are overpowering, as nearly all the large ocean steamships recently constructed abroad have such engines. One of these vessels, 400 ft. long, according to the statement of a representative, crossed the Atlantic inside of 12 days, with a consumption of only 40 tons of coal per day.

THE BALANCE DOCK BASIN AT POLA.*

The harbor of Pola, naturally favorable for the purposes of a naval station, was selected by a committee of Austrian engineers and officers, as the most suitable that could be chosen for the extensive arsenal and dockyards, which it would be necessary to construct when the port of Venice was abandoned. It was situated directly south of Trieste, on the western coast of the peninsula of Istria, south-west of Fiume, and about 60 miles distant from both those ports. Venice, on the other side of the Adriatic Sea, was 80 miles distant in a north-westerly direction.

It was at first intended that excavated docks should be formed, but in consequence of the volcanic and treacherous nature of the ground, this idea was found to be impossible of execution. A Floating Dock, Basin, and Railway system were therefore decided upon, the dock adopted being that known as Gilbert's Balance Floating Dock. The basin and railways were in general principles the same as those constructed at the United States Navy Yards at Portsmouth, New Hampshire, and at Pensacola, Florida. These were the first dock basins with railways that had been constructed, and were commenced in the year 1849.

The function of a basin for a floating dock was to supply a place in which the dock itself might be grounded, either with a vessel upon it to undergo extensive and prolonged repairs, or to enable the vessel to be hauled out of the floating dock upon the railways, which latter operation was only required in cases where vessels were moved from the dock to land above the sea level, or the reverse. A basin to fulfil these requirements must be so constructed as to permit the dock to be floated into it, and the entrance closed by means of gates or caissons.

The general dimensions of the basin at Pola, determined by the magnitude of the floating dock, were as follows :

	Ft.	In.
Width inside the enclosing walls.....	211	6
Length.....	311	6
Depth from the top of the walls to the stringers in the floor of the dock...	17	1½
Depth from the level of ordinary high water to the top of the stringers....	13	0
Depth from the level of ordinary low water to the top of the stringers...	11	0

The maximum difference in the hydrostatic head, inside and outside the basin, existing during the progress of the construction of the basin, was 20 ft.

Detailed surveys and sections of the site were taken, so as to determine the precise contour of the rock, and of the mud overlying it, which varied in thickness from 2 ft. to 12 ft. As the rock was unfitted for holding, or even for receiving sheet piles, except when they happened to strike a fissure, it was decided not to use the ordinary clay-puddle cofferdam.

The material selected for the walls of the basin was Santorin béton, composed of Santorin earth—a volcanic product from the Greek island of Santorino—and lime paste, in the proportion of 7 to 2, forming the hydraulic mortar; to this was added 7 parts of broken stone, the mixture being made into a conical heap and tempered by exposure in the open air for from one day to three days, when it was ready for use. Of this béton extensive wharves and moles had already been constructed at Trieste, Fiume, and Pola; and, as it had been found durable and efficient, was moderate in cost, and obtainable in any quantity, it was considered that no better material could be determined upon for the walls of the Pola basin. It might be mentioned that the largest blocks previously made were those at the mole of Fiume, which were 25 ft. in vertical depth, 22 ft. wide at the top, with a batter of 1 in 4 or 1 in 6, and 50 ft. long.

It was believed that, by adopting proper precautions, the mud which covered the rock bottom would form a suitable foundation for the walls of the basin, provided that a water-tight joint could be made at the bottom of the wall, for there could be no leakage or percolation through the béton, so long as it remained uncracked by unequal strains or settlements. It was, however, assumed that such cracks would occur, and that it would be necessary to provide for such a contingency.

A wall of a plain rectangular section

* From a paper read before the Institution of Civil Engineers, London, by HAMILTON E. TOWLE, C. E., of New York.

was decided upon, the thickness of which was determined with reference to the fact that the foundation consisted of greasy mud, lying at angles varying from 2 deg. to 10 deg., which would render a slip possible. Joints were made across the wall, at intervals of from 40 ft. to 90 ft., in order to form weak places, which, being selected with reference to the nature of the bottom, would in all probability determine the location of any cracks that might occur.

It was ascertained by calculations, based upon the data afforded from a knowledge of the contour of the rock bed and the mud bottom, that no crack could exceed 6 in. as a maximum, and the ends of the blocks marked the localities where the settlements would probably take place. To check the passage of the water through the wall at these points, as well as to prevent the blocks from moving laterally upon one another, a rectangular post, 18 in. by 24 in., was inserted vertically in each of the joints, reaching from the upper surface of the block, through the mud, to the rock bottom below. These posts projected 12 in. into each block of béton. Subsequent experience proved that this device was thoroughly efficient, the largest crack, which had a maximum width of 5½ in., not admitting any water. The thickness of the walls varied from 15 ft. to 20 ft. and 26 ft. The floating dock entrance was placed on the north side, and was adapted for an iron caisson to close it. This entrance was 120 ft. wide in the clear, but the caisson measured 128 ft. along the top line. The pump well was situated in the south-west corner of the basin. Great care was taken to make the stage piles stand vertically, as they were to remain permanently in the walls. The vertical diagonal bracing between the piles was removed as the béton was filled in. The enclosing sheet piles were carefully squared, so as to obtain perfectly true faces, for the purpose of obtaining tight joints, and to give the béton walls, of which the sheet piles formed the moulds, a fair surface.

To facilitate the operation of driving the piles in line a machine was specially devised by the Author, and termed by him a "spider." This consisted of two horizontal timbers, 35 ft. long, placed parallel to each other and kept 12 in. apart (12 in. being the thickness of the sheet piling) by distance pieces. From the forward end of these timbers, two other timbers, also 12 in. apart, sloped backwards and upwards, while at about 8 ft. from the same end an oak block was passed between and bolted to the horizontal timbers, and this also sloped backwards and upwards, until it intersected the other two raking pieces before described and was bolted to them. This frame was hung by two vertical rods of wood to the staging above, and was free to swing to and fro; ropes and tackle were attached at the rear end, by which the frame could be moved in any desired direction, while, by a strong hawser fixed to the forward end, the jaws, formed by the horizontal timbers and the raking pieces, were made to embrace closely a short length of sheet piling already driven, the machine being hauled up so taut by the hawser that the raking oak block pressed against the face of the pile. The distance at which the "spider" was suspended from the staging was such, that the end of a pile about to be driven was engaged in the guide formed by it before its vertical position was affected by its tendency to float. When it was in operation the hawser at the forward end was hauled tight, and the end of the pile, pressing against the guide, extended the rope sufficiently to force the "spider" back, and permit the pile to pass and be driven in its exact position. It was found by experience, that with this machine at least double the amount of work could be done, and all the piles were kept exactly in their proper position.

When the sides of the enclosure for one block had been completed, and the cross dams and the vertical timber joint before described had been put in, the section was bolted together above the level of the béton work, and the operation of filling in was commenced, the average time required for this being two weeks. After the walls had been finished, the tie bolts clamping the sheet piles against the sides of the blocks were gradually loosened, to enable the former to settle freely and to compress the mud from below. At the same time the interior rubble wall was built upon the top of the béton, to a level above high water, to form a dam. The sheet piles were subsequently cut off by a circular saw, and the exposed ends were

covered by an external sloping embankment, or apron, of broken stone and sand. The principal internal filling of the basin having been completed as the previous work progressed, as well as a temporary clay-puddled coffer-dam closing the opening for the iron caisson, the pumping machinery was erected, and on the 2d of February, 1859, the operation of emptying the basin was commenced.

As was anticipated, the butt joints between the béton blocks were found to open, more or less, according to the character of the mud on which they stood. and the contour of the rock bed, but in no case did the timber joints fail. After the maximum settlement had developed itself, the cracks were carefully cleaned out, and filled with masonry to the depth of 1 ft. from the face of the wall, and tubes or pipes were inserted in the wall, for conveying away any slight leakage that might escape, without washing away the fresh mortar. Where a crack or joint appeared open on the external side of the béton walls, a pad, secured to a plank or timber, was firmly braced against it, until it was tight enough to prevent the escape of fine mortar or cement. The openings or cracks were then filled with thin grout, injected through a tube, under a head of about 10 ft. above the wall.

As soon as the basin was emptied, the work of laying the floor was commenced. This consisted of 30 rows of foundation piles, capped with timber 1 ft. sq., bedded in 6 in. of béton. Upon the top of the piles was fastened close planking 6 in. thick, and over this was laid the masonry, forming and completing 9 lines of stringers, varying from 8 ft. to 12 ft. in width, to receive the bottom of the dock when grounded.

The space of several hundred feet between the southern end of the basin and the island (Scoglio d'Olivie) was filled in, and two sets of railways, resting on pile foundations, were laid.

The caisson for closing the opening to the basin was built by the Messrs. Rennie, of London, and was found to answer its purpose completely.

ERECTING BRIDGES WITHOUT SCAFFOLDING.

From "The Engineer."

The Jumnah, the Saone, the Sutlejh, and many other large rivers of India have been already spanned by railway bridges, but as yet the Ganges has never been polluted by the shadow of a locomotive thrown upon its sacred waters. That event is, however, close at hand. The Oude and Rohilcum Railway crosses that river at Cawnpore, and the structure that is to convey the trains across is in process of rapid construction at the premises of Messrs. Campbell, Johnstone & Co., at Silvertown. It is intended to adopt, not a new principle, but a novel method of erecting this bridge ; and it was to witness the application of this method that a large party of engineers and other gentlemen interested in such matters proceeded on Friday week to the works of the firm in question. We will describe, first, the bridge, and then the manner in which it is proposed to dispense with the adventitious assistance in scaffolding and staging. The bridge may be stated to be a tubular lattice, if that term may be used with propriety. It is intended to carry a double roadway, one over the other, consisting of a single line of rails and an ordinary thoroughfare. The latter is carried in the lower portion of the structure, and the former overhead. As the weight of the traffic on the roadway may be regarded as insignificant compared with that on the rails, the girders may be considered, as far as the rolling load is concerned, as loaded on the upper booms. This might be surmised from the large quantity of bracing disposed horizontally between them. Looking at the girder in elevation, it is divided into so many panels by vertical compression members, which have the appearance of being carried across the space between each pair of parallel girders, both above and below. This arises from the fact that the lower and upper cross girders are placed at the junction of the verticals with the booms. In the transverse section the cross girders and verticals compose a system of rectangular frames which unite the separate girders into one structure, and constitute the skeleton or frame-

work of the whole bridge. The girders are evidently designed in accordance with an axiom that is an especial favorite with some engineers: "Always make your struts as short as possible." We shall not now enter upon any discussion of the real economy of this principle of construction, but merely state that vertical struts and diagonal ties do not necessarily make an economical bridge. When the rolling load is considerable, compared with the dead weight of the structure, the bars of the web, near the centre particularly, have to support strains of both tension and compression, and counterbracing of some sort must be introduced. At the centre of the girders under notice intersecting diagonals are introduced for this purpose, but theoretically the effect of these, as there are vertical bars as well, is only to cause a confusion in the direction of the strains, and practically a superfluous amount of material. But as this reduplication of the bars of the web occurs at the central bay only of the girder, it is of no importance, and in all other respects, omitting the consideration of the principle, the web is a good specimen of lattice work. It is entirely free from the common error, perpetually displayed, of placing the bars too closely together, and, at the same time, the distance between them is so adjusted as to allow of the conditions, assuming a uniform distribution of load on the flanges, being practically fulfilled. As the strains upon the flanges can only be induced through the medium of the connecting bracing or web, the distance apart of their relative connections must determine whether the former are strained progressively from the ends towards the centre, or whether "per saltum." It is not necessary to remark that in the latter case, the girder would have to be constructed in an especial manner that would be usually troublesome, complicated, and expensive.

The minimum number of spans that must of necessity be made continuous, either temporarily or permanently, to enable a bridge to be erected without scaffolding, is two. When the girders covering the double span are in position, there will be three points of support, and when they are in motion there will never be less than two. Before describing the actual manner in which the continuous girders traverse successively the various points of support, until communication is established across an inaccessible distance, a word must be said about the special apparatus employed in the experiment. Briefly, it consists of a set of hydraulic presses, supporting at their upper extremity a number of wheels. The bottom flanges of the girders are furnished with a tee-shaped longitudinal piece of wrought-iron. The rib of this rests upon the periphery of the wheels. The latter are caused to revolve by being connected with toothed wheels, which are worked by an endless screw. As they revolve, the friction upon the rail is sufficient to produce the advance of the girders. Five men are required at each side of the pier or support, so that, in all, ten men are sufficient to move the pair of continuous girders. The whole manipulation is exceedingly simple and efficacious. Let us now investigate the mode of erecting the bridge on its permanent site, bearing in mind that there are 23 spans, each 100 ft. in length, and a couple of land spans of smaller dimensions. It is only the actual framework or skeleton of the bridge that will be launched from pier to pier in this manner; the two platforms, that of the roadway underneath and that of the railway above, will be laid afterwards. In the first place, the two pairs of continuous girders must be riveted up with their connecting bracing complete on the solid ground, in the rear of the abutment which is to constitute the starting point. If we call these girders Nos. 1 and 2 we have them supported at three points, with the free extremity of No. 2, reckoning from the land, resting upon the abutment, and ready to be launched into space. In this position there are three sets of presses and rollers required. One set is on the abutment, another is on the point where the two separate pairs of girders are continuously united, and the third is on the bridge, to be used as will be shown presently. The free end of girder No. 1 is merely supported on packing, as the least movement will cause it to swing clear of its bearings. The object is now to launch the girder over span No. 1. The ten men go to work on the abutment at the screws, and girder No. 2 commences to advance into space at the rate of 40 ft. per hour, so that, allowing for contingencies, it will

reach the first pier in three hours' time. Directly the intervening distance is spanned the set of presses that has been carried over the space with the bridge is placed under the girders on pier No. 1, while at the same time the set that was originally under the centre of the continuous span, but is now under the free end of girder No. 1, is removed and placed on the bridge, to serve in its turn for pier No. 2. A repetition of this operation carries the continuous girders right across the river, until they occupy the twenty-second and twenty-third spaces respectively. The set of presses and rollers are conveyed back again, and the same process recommenced with another pair of continuous girders. Bearing in mind that the common difference is equal to two spans, it is readily calculated that at this rate it would take six weeks or two months to get all the girders in their permanent positions, not including the time necessary for fixing them.

The experiment having been very successfully carried out, which included the moving of the girders forward some 20 ft. or 30 ft., the party, numbering about five-and-thirty, adjourned to luncheon, provided with much taste and hospitality by Messrs. Campbell & Johnstone, in the spacious upper story of one of their workshops. Sir John Rennie was in the chair, with Mr. Heppel at his right hand, and after a few toasts the visitors left for London by an early train, after expressing the satisfaction and pleasure the trip had afforded them. It is, of course, one thing to carry out an experiment in a workshop, where there is an entire absence of wind, and other disturbing causes, and another to perform the same feat upon the site of the bridge ; but from what we have witnessed we have little doubt respecting the actual success. At least we hope there will be no hitch, for should one of the girders happen to topple into the river, the Hindoos will be certain to ascribe it to the anger of their deity, and a just punishment for invading the sanctity of the holy stream. Regarding the effect upon the girders themselves of this method of erection, we shall have something to say on another occasion.

AMBIGUITY IN TESTS OF IRON-WORK.

From "The Mechanics' Magazine.

The usual assumption, so frequently put forward, that because any piece of mechanism, or any structure of iron or other material, has once withstood a given pressure or strain, it will in future not give way under one of a less amount, must not be received unreservedly. Its subsequent safety and immunity from danger from strains of a lesser severity than those which constituted its proof test, will depend, not so much upon the actual magnitude of the force applied, as upon the proportion the strain bears to the limits of elasticity of the material. On the one hand, it would obviously be exceedingly remiss on the part of those responsible for the strength of any structure to permit it to be employed in situations where its failure would be attended with fatal results, without subjecting it to some kind of test or proof, in order to obtain a practical and reliable knowledge of its resisting capabilities. Again, on the other hand, it would be erring in the other extreme to cause the proof applied to be so excessively severe in character as to jeopardize the future security of the structure. Much difference of opinion prevails among engineers on this point. Some consider that the ratio of the testing to the breaking strain of the material should be very high, while others advocate the employment of more moderate proof strains. In our opinion the latter is the more judicious of the two methods. A moderate proof load is quite sufficient to demonstrate whether the example in question is able of performing the ordinary duty that will devolve upon it, while a very severe one cannot do more, and at the same time may permanently damage the structure. The over-testing of any piece of mechanism or example of construction may be not inaptly compared to the over-training of a young athlete. When the powers are over-taxed, they are inadequate to perform their work when the time arrives. It should be borne in mind that the mere capability of resisting, without indicating

palpable symptoms of weakness, any given strain, is not by any means an absolutely reliable criterion of the strength of any piece of construction. If the example be of a complicated nature, there is the character of the workmanship to be taken into account as well. It might be executed in such a manner that, while capable of withstanding a heavy strain upon it for a short time, it would infallibly give way under the continued application of one of a considerably less amount. Independently of the reasons that we shall refer to which indicate that excessive proof tests should not be used, there is the undeniable fact that iron structures do subsequently yield under a much less strain than that which they bore apparently with ease at the time of testing. What is more common when one of these catastrophes occurs than the exclamation "Oh! it bore three times that load when it was tested?"

It was but the other day that a crane broke while used for lowering some workmen, and the accident terminated fatally. It is stated that the load which occasioned the fracture was 12 cwt., and that the crane had previously been tested with a proof load of a couple of tons. Here we have an instance of a specimen of iron construction giving way under a load that is three and a half times less than that which it withstood with impunity as a test. This is one of the most recent examples that has come under our notice, but it would be easy to give a long list of similar ones that have occurred at intervals ever since the introduction of cast and wrought iron as materials suitable for engineering and architectural construction. The fact of the subsequent yielding of iron-work to strains inferior to those with which it was taxed at its proof trial is not confined solely to small specimens such as cranes, but is equally true for larger and more pretentious structures. Bridges that have successfully passed the ordeal prescribed by the regulations of the Board of Trade have subsequently been found to fail under loads of a less amount than those which constituted their preliminary trial. A railway bridge that is passed by the Inspecting Officer of the Board of Trade as perfectly safe for traffic may, in the course of a few years, become so insecure as to require extensive repairs before it can be again used for locomotive purposes. This result may proceed from one of many causes. It may be due to an originally bad design, defective workmanship, inferior quality of material, or to a combination of these. A well-known instance in point is the Crumlin Viaduct. This is a bridge belonging to the Warren type of girder, in which the connections between the web and flanges are made by pins instead of rivets. It may be observed that this principle of attaching the web and flanges is adopted in the Charing Cross Railway Bridge, but, nevertheless, it will never make so complete or so rigid a connection as when the pins are replaced by rivets. This was found to be the case with the Crumlin Viaduct. The pins got loose, as all pins must inevitably do in the course of time, and it was necessary to make good the attachment of the web and flanges with gusset pieces and rivets. This was effected, and the structure placed once more in a condition fit for traffic.

Returning to the subject of the test load, it may be asked what should be the maximum strain that ought to be imposed upon a structure of wrought iron, in order that while, on the one hand, its capabilities for resisting subsequent strain should not be impaired, on the other, those capabilities should be put to a reasonable proof. It must be borne in mind that action and reaction are equal and opposite, or in other words, Hook's law, *sic tensio, ut vis*, holds good for iron up to a certain point. It is impossible to arrive at the exact strain that, preliminarily imposed upon any particular structure or piece of iron-work, will impair its future powers of resistance. Evidently, in this case, a great deal must depend upon the character of the example experimented upon, and whether its design be simple or complicated. If it be of the latter description, and composed of a great number of individual component parts, which are attached to one another by bolts or rivets, the first effect of the test load will be to adjust the relations of these parts, or to bring them all to their bearings. A portion of the load may therefore be fairly considered to be absorbed in accomplishing this mutual arrangement, and it is not until this result is effected that the structure becomes really sensible of the strain applied to it. Those who have had ex-

perience in the testing of iron girders, especially those intended for locomotive traffic, are well aware of this fact. The action of the test load is rendered manifest by the deflection of the girder, and it is a well-known and remarkable circumstance that the deflection of a girder, when first tested, is always greater than that arising from a repetition of the same load. Clearly, this is due to the adjustment of the parts, as already mentioned. When they have once been brought to their bearings, there is no further deflection to be obtained from their action. In mathematical language, the quantity representing their deflection has been eliminated from the calculation. There is, therefore, a difference between the deflection first observed in a girder submitted to a certain proof load, and that which attends the girder under a repetition of the same load. This difference may be great, or it may be small, and its proportion will depend upon the superiority or inferiority of the workmanship. The better the workmanship the closer and more firmly will all the parts be united together, and enabled to act as one solid mass, rather than as a combination of numerous component parts. To a certain extent, therefore, the difference between the first and any subsequent deflection of a girder under a given load may be regarded as a criterion of the character of the workmanship. Viewed in this light, there is an ambiguity in the test, as it is not solely a measure of the absolute strength of a girder, but also of the nature of the workmanship.

The fact of the difference in the first and future deflections of a girder under the same proof load not being a complete indication solely of the character of the workmanship, is due to another circumstance which we shall now refer to. If the adjustment of the relative parts were the result only of practical imperfections in the methods of their attachment to one another, there would be no necessity for going any further. But there is another cause which must be taken into account also, when the example is of a complicated nature similar to that under consideration. In a girder composed of an open web and upper and lower flanges, one half of the diagonals, under the ordinary conditions of a superimposed weight, will be in tension, and the other half in compression. But these strains of tension and compression will not be produced, at least not to any very appreciable extent, until the load is placed upon it. It is evident that the bars will receive their initial straining from the test load, and will afterwards not to be so susceptible of the effect of any force applied. It might be perhaps remarked here that, as the deflection of a bar or of a girder is approximately a measure of its strength, a bar or girder that deflects less on the second or other succeeding application of a given weight ought to be stronger than it was when first subjected to its influence.

At first sight this may appear a little paradoxical, but it is nevertheless the fact, at any rate so far as the deflection may be considered a criterion of strength. So well is this principle known that it is a common, but at the same time a very reprehensible practice to place heavy weights upon a girder or iron structure that is liable to a Government inspection and testing. By thus subjecting the structure to a preliminary proof, it exhibits consequently less deflection on subsequent testing. As deflection offers the readiest and in many instances the only means of arriving at an estimate of the resisting capabilities of a structure, it is no wonder that it sometimes passes for being stronger than it really is.

The limits of elasticity of wrought iron have been stated by different writers at various figures, but this discrepancy may possibly arise from the fact that different qualities of iron were employed in the experiments. Mr. Barlow, a well-known authority on all such matters, found it to be about 10 tons, while other equally able and reliable experimentalists have determined it to be as high as 12 tons and more. There is no doubt that iron of a superior quality might be fairly considered to possess a range of elasticity reaching to 12 tons, but when it is borne in mind that the majority of iron-work is rarely constructed of any but ordinarily good iron, it will be far safer to take the lower amount for the standard of calculation. This should be more especially kept in view when the iron-work is designed to fulfil a duty that will subject it to the action of forces of a concussive or impactive character. The effects of overstraining, particularly if it be accom-

panied by shocks and sudden violent wrenchings, is to render iron that is otherwise of a soft ductile nature, exceedingly hard and brittle. In fact, there is very little doubt that incessant repetitions of impactive forces tend in the course of time to completely alter the molecular constitution of the material, and, in a word, to convert wrought iron into cast. In instances where wrought-iron chains have been fractured after withstanding for some years violent jerks and shocks, it has been very difficult to discover any evidence that the material was originally wrought iron, the section of fracture resembling that of cast iron, scarcely a trace of any fibrous consistency remaining. Whatever, therefore, may be the character of the material, or the design of the structure it is clearly unadvisable to subject it to any proof strain exceeding the limits of elasticity.

THE PROPERTIES OF ELASTIC TIRES.

By LIEUT. CROMPTON, R.E.

From 'The Engineer."

The question of elastic tires as applied to traction engines, heavy guns, in fact, to any wheeled carriages intended to cross soft or rough ground, is one that is exciting considerable interest amongst the mechanical engineers of the day, and the object of this paper is to draw attention to the various advantages as well as disadvantages of the system, and to bring to the notice of the engineering public several properties which appear to have escaped general attention.

Throughout this paper I use the word elastic tires, meaning thereby tires possessing elastic properties in the highest degree at present obtainable. I have not hitherto met with any arrangement of metallic spring tire that can be at all called elastic in the same sense that rubber is elastic, *i. e.*, capable of restoring by its instantaneous expansion in rear of the wheel nearly the whole of the power expended in compressing it in front of the wheel. The reader must therefore understand that whenever the words elastic tires are used, solid ring tires of the best and softest rubber obtainable in the market are meant. The properties of elastic tires are—(1) Their effect in reducing rolling resistances over rough or soft surfaces; (2) in producing increased bite; (3) their use as friction brakes; (4) use as springs; (5) in reducing wear and tear of engine; (6) in reducing wear and tear of highway.

To compare the rolling resistance of a train and wagons mounted on rigid wheels with one mounted on wheels with elastic tires, I will put six cases likely to be met with in ordinary work across country, and note in a tabular form the rolling resistance in each case in pounds per ton.

Case 1.—Over very good pavement. In all these cases, for the purpose of argument, the question of slip, etc., being laid aside, the way level and straight :—

Rigid tires, supposed to be rigid steel rollers, 5 ft. diameter, 12 in. wide on face of tire.	Elastic tired wheels, rubber tires 4½ in. thick, 5 ft. diameter over all, 12in. wide on face of tire.
Total resistance... 60	Total resistance... 70

Case 2—Over good macadamized road in fair order, all conditions as above :—

Rigid.	Elastic.
Total resistance... 70	Total resistance... 70

Case 3.—Over ordinary macadamized road of an average quality :—

Rigid.	Elastic.
Total resistance...120	Total resistance... 80

Case 4.—Over road newly coated with gravel :—

Rigid.	Elastic.
Total resistance...300	Total resistance...100

Case 5.—Over newly-broken stone, other conditions as above :—

Rigid.	Elastic.
Total resistance...440	Total resistance...110

Case 6.—Over soft grass land :—

Rigid.	Elastic.
Total resistance...300	Total resistance... 80

I do not pretend to extreme accuracy in these figures; but they are sufficiently near the mark for all purposes of comparison, and will be substantiated by any one who has ever used rigid and elastic tired traction engines working side by side, as was the case with the writer for many months together. But any one who

has ever been in the omnibus fitted with Thompson's rubber ring tires, that ran for some time between Leith and Edinburgh, cannot have failed to notice that, running over pavement, macadamized broken stone, or soft muddy road, it was all one to the engine that drew the omnibus, and hardly any variation in her pace, which was that of a fast horse omnibus, could be observed.

The apparent cause of the superiority of the elastic over the rigid tires, in cases 3, 4, 5 and 6 is this, that the principal cause of rolling resistance, on a road more or less perfect, is the inequality or roughness of the surface. The wheel is always either ascending or descending minute prominences on a good road, larger ones on a bad one, or if the load on the wheel be heavy enough, in crushing them to a nearly level surface, and so much resistance is due to this that it amounts in an extreme case, viz., that of a road newly covered with broken stone, to one-fifth of the weight carried on the wheel. The elastic tire, on the other hand, allows these prominences to sink into its under surface, preserving all the while a tolerable level on its upper surface. Let the reader imagine to himself a level macadamized road, half of which has been carefully rolled by a steam roller to a nearly perfect surface, the other half being covered with loose road metal. If the rigid wheels I have taken as an example be drawn over these two surfaces in turn, the resistance will be found to be. 65 lbs. per ton over the rolled, and 440 lbs. over the loose surface; let both surfaces be completely covered with a carpet of rubber, 4½ in. thick, and the same wheels be then drawn over them, the resistance over the rubber which covers the rolled surface will be 70 lbs., and over that which covers the loose part will be only 110 lbs. We do not exactly know to what the increased 5 lbs. in the former case is due, but no doubt some part of it is expended in overcoming the friction of the rubber when it is expanding laterally over the smooth surfaces of the tread of the wheel and of the road. In the latter case considerable additional power is expended in forcing the rubber into intimate contact with the very uneven surface of the road; still, however, the gross resistance met with is only one-fourth of that over the bare loose surface.

Let the reader now imagine a strip of this carpet, of the exact width of the tread of the wheel (which must be so proportioned as not to sink into the rubber to an injurious extent) to be cut out, and the ends brought together, and joined so as to form a solid ring. We have now the elastic tire, the properties of which I am describing, and which behaves in exactly the same manner in affecting rolling resistances as the complete carpet of rubber does.

The question of the superior bite of the elastic over the rigid tire reduces itself to a question of extent of surfaces in contact. In the case of the rigid tire this surface approaches *nil*, or a theoretical line, according as the wheel and road are more or less rigid and unyielding. In the case of the elastic tire it varies as the thickness and softness of the rubber. To take an example:—A 6-ft. diameter rigid tired wheel on a macadamized road with a good foundation, width of tire 18 in., has a surface of contact of, say, at the utmost, 18 in. × 2 in. = 36 sq. in. An elastic tired wheel, tire 4½ in. thick, also 6 ft. diameter over all, same width, and loaded to same weight, say three tons, will have a surface of contact with a similar road of 18 in. × by 18 in. = 324 sq. in. if gray rubber be used, or 18 in. × 24 in. = 432 in. if red rubber be used. In the first case we have 9 times, and in the second 12 times the surface. I may here notice that this enormously extended surface will at once explain the marvellous properties of elastic tires when going over soft ground.

Some of my readers will at once exclaim, "But one of the first axioms in mechanical engineering is that the friction of the rubbing surfaces does not vary as their area, but as the weight which forces them together." To this I reply that this axiom only applies to bearings or other rubbing surfaces of machinery, which are made as smooth as possible, and carefully prevented from coming into direct contact, and thus interlocking by the interposition of some lubricant. But let these two mechanically smooth surfaces be encouraged to interlock, by taking away the lubricant, and artificially roughening them with small teeth or other asperities, the axiom above quoted will no longer hold good; and if several sets of bearings or rubbing surfaces thus roughened be taken, all carrying the same load but varying in area, the friction will be found to increase

with the area; and the case of a wheel rolling on a road is precisely similar—one at least of the surfaces is soft enough to allow the asperities of the other to sink into and interlock with it. The rigid tire sinks into the road, and the elastic tire allows the road to sink into it. In either case we have interlocking, but of course in the latter case we have extended area—hence the increased bite. The bite obtainable for tractive power from these increased surfaces amounts in extreme cases to 65 per cent. of the load carried on the wheel. Some experiments were carefully carried out in France with traction engines, under the superintendence of Messrs. H. Tresca and General Moran. From their report, dated February, 1868, I learn that the utmost coefficient of adhesion of a rigid wheel upon a dug macadamized road in a good state of repair is 30 per cent. of the load carried on the wheel.

The following table will give at a glance the advantages possessed by the elastic tire:—

Case.	Percentage of adhesion	Description of engine, wheel, road, etc.	Remarks.
A	17	Rigid wheel on a dry paved street.	Experiment made on of 1-16.
B	20	Elastic tired wheel on hard frozen ground coated with ice; tire consisting of segments of very hard rubber held in their places by shoes.	Do. do., 1-13.
C	27	Ordinary rigid wheels on good macadamized road in dry weather.	Do. do., 1-12.
D	29	Elastic tired wheels over hard frozen ground coated with ice, being solid ring tires with shoes on.	Do. do., 1-20.
E	30	Tresca and Moran's limit of adhesion for rigid wheels on very good macadamized road.	From many experiments on levels and on an incline, 1-30.
F	26	Elastic tired wheels over clear hard ice, being solid ring tires without any shoes.	On an incline, 1-11.
G	55	Adhesion of elastic solid ring tires with shoes over them on fair macadamized road.	On various inclines, computed from many experiments.
H	65	Limit of adhesion of solid elastic ring tire with shoes over them on good macadamized road.	On an incline, 1-20.

It will be noticed that I have given no cases of rigid tires being tried on unfavorable roads, such as in cases B, D, and F, or on greasy paved streets, greasy macadamized roads, grass land, clay, sand, etc., the reason being that rigid wheels possess practically no adhesion at all on such surfaces; and if a traction engine be taken out under such circumstances she will be unable to move herself, let alone her load, and has to be helped home by other power.

In case F, the data were obtained from calculations based upon the work which has been done during the late hard weather by a traction engine belonging to Mr. White, of Kettock Mills, near Aberdeen. By the constant flow of water over the steepest part of the road, a mass of solid ice was formed on an incline of 1 in 11, and on such a surface the engine found no difficulty in taking herself and her load, total 16 tons, at a considerable speed, with a consumption of fuel of 1.75 lb. per ton per mile (gross load, including weight of engine).

Any one who has ever driven a train of wagons, drawn by a traction engine along a highway, must have noticed that it is absolutely necessary to make all the couplings between the engine and wagons perfectly rigid, so as to allow no longitudinal play, not even so much as in an express train on a railway. Consequently, if the engine be geared directly to her driving wheels, without the intervention of a friction brake, it will require an unnecessary powerful engine to start a heavy train, and all traction engine makers have found this friction brake necessary; but it is extremely difficult to adjust to the load, and requires constant attention. If, however, the elastic tire consists of a solid rubber ring, slipped over the driving wheels (which have their peripheries turned up perfectly smooth) and kept in its place by flanges, it forms the most perfect friction brake we know of.

When the engine is starting a heavy train, the driving wheels make some portion of a revolution within the tires, varying with the load, and the train gathers way, and moves off as smoothly as it is possible to conceive, even if the regulator handle be opened full at once. There is no wear and tear of the internal surfaces of the tire, in consequence of this use as a brake. The sand or mud, or whatever foreign substance gets between the periphery and the tire, beds itself in the rubber, and wears down the periphery of the wheel, but leaves the tire practically uninjured. So much so is this the case, that an engine in India, after running some 2,000 miles over the dustiest roads perhaps in the world, exhibited literally no wear whatever on the inner surface of her tires. I lay stress on this fact because it has been stated that great wear and tear took place on the inner surfaces, because it was out of sight it had not been noticed by the general public.

The quality of the rubber used is of great importance in its effect on the adhesion of the tires and of their durability. Red rubber, although it is most expensive, and, being softest, gives the greatest percentage of adhesion, is very uncertain in its composition, and, consequently, is not to be trusted to for tires intended for extreme climates. Gray rubber, which is much cheaper, is harder, but can be thoroughly depended on. Some other kinds of rubber, still harder, have been tried, but there appears to be no gain in their wear as regards durability, and considerable loss as regards adhesion and use as springs.

Traction engine makers for years past have been endeavoring to perfect some arrangement of springs by which the injurious vibration caused by the jolting over a rough road might be lessened, and as yet no springs have been fitted that will work, for this reason—that if the driving axle does not maintain its parallelism with the crank shaft, but constantly varies its position, the effect will be that each end of it will at one time overrun, at another time lag behind its own end of the crank shaft, the torsional strains on which will be so great as ultimately to cause its failure, particularly if the engine be worked at any speed. The elastic tire, however, forms a very perfect spring, and, as it is placed in the most favorable position in which a spring can act, viz., between the wheel and the ground, instead of between the load and the wheel, it not only preserves the load—that is, the engine itself—from injurious jolting and vibration, but reduces the wear and tear on the wheel itself and its axle to a minimum. This is not the case with the ordinary spring, as the wheel and axle, being between it and the road, have full liberty to use their whole momentum to pound themselves and the road to pieces. Traction engines, fitted with elastic tires, have consequently been able to attain high speeds of 10 and 12 miles an hour without injurious results to the machinery. In fact, in the case of the Indian engine above quoted, the vibration felt by any one standing on the foot-plate when she is running at 8 miles an hour, over a macadamized road in fair order, is infinitely less than that of an express engine running at the moderate speed of 30 miles an hour over good track.

The wear and tear of highway when traction engines or other wheeled carriages having rubber tires are run over it is absolutely *nil*. When guards or shoes are used over the rubber it becomes appreciable, but is still so small that no other wheeled carriage can compare favorably with them, even if ever so lightly loaded. I will quote a case of a section of road in India, which, being in front of workshops, was traversed by an engine with rubber tires weighing 6 tons many times daily. This road was formed of broken bricks, and was repaired annually after the rains; however, the year that the traction engine ran over it this annual repair was found unnecessary, as there was not a rut or depression worn in the surface of it. I leave it to the imagination of the reader to consider what would have been the state of this rubbly brick road after a month or so if a traction engine of the same weight with rigid tires had been running over it. To see a heavy engine with rigid tires going up a paved street, breaking every joint, and leaving a zigzag line of cracks between every paving stone after the driving wheels have passed over it, is indeed a painful sight to a road surveyor, and no wonder can be expressed that the opposition to the extended use of traction engines is so great. But it would puzzle the same surveyor to find out where the engine on elastic tires had

been, even if she had followed the same track daily for months.

Experiments were carried out at Chatham to show that elastic tires possessed slight advantages over rigid ones, in fact, so slight, that the money laid out in them had far better be laid out in improvements in the engine itself, such as putting in steel for iron wherever possible, etc.; and these experiments will doubtless be quoted to disprove the arguments I have put forward; so I will briefly state what was done, and what was proved by these trials.

Elastic tires were applied to an engine belonging to the Royal Engineer Department. These tires were made up of segments chemically attached to plates of metal, which were again bolted to the peripheries of the driving wheels. This engine, so fitted, was put into competition with an engine on rigid tired wheels, but in all other respects similar; and, roughly speaking, those who conducted the experiment, considered that the elastic tires possessed $\frac{1}{6}$th or $\frac{1}{7}$th more adhesion, or bite, than the rigid ones; and that this, as I have said above, hardly warranted their cost.

Now it will be observed that the bite question alone attracted their notice. Friction brake, springs, diminished wear and tear of engine, and of highway, were alike ignored; and yet the want of any one of these is sufficient to condemn a traction engine. Even as regards bite, the results observed were so fallacious that they are not worthy of notice. The rubber used was so thin and hard that the surfaces of contact were very small, and the bite consequently very different to what it would have been had the driving wheels been fitted with the best description of elastic tires, viz., solid rubber rings $4\frac{1}{2}$ in. thick; and the surface of the road was in a very favorable condition for the rigid tire, being hard and dry, with a good coating of grit on it. This condition of road is the most favorable one possible for a rigid tire, but such roads are not very abundant, and traction engines with rigid tires have hitherto failed because they are always coming to a stand-still on paved streets, sandy, wet, greasy grass, and all manner of soft roads and grounds. If the two engines at Chatham had been tried over all these varieties of road, the elastic tired engine, bad as it was, would have showed vastly superior bite to the other, and would have had, over and above, all the advantages I have above mentioned as being completely ignored by those conducting the experiment.

ARCHITECTURAL PROBLEMS OF THE DAY.

From "The Building News."

We noticed a week or two since two very different sorts of originality which show themselves in various classes of modern work: one sort sterile, purposeless, and ending in itself; and another fruitful, suggestive, and bearing the germs of future development; and we tried to point out that the valuable kind of originality is not that of the artist who sits down deliberately to produce novelties, but of the one who, having new problems to deal with, inevitably finds, when he has mastered them, that he has arrived at new solutions. There is no lack of such problems at the present moment—seldom perhaps, since architecture first began, have there been so many; and in calling attention to a few of them we may possibly help to turn into a useful channel some of the force which is now wasted in vain and aimless efforts. To arrange in a connected scheme all the questions which occur would occupy, not an article, but a book; we can here only attempt to name a few of them disconnectedly, as they happen to suggest themselves.

The first, and most urgent class of problems, includes those which relate to general design and arrangement. The modern architect has to deal with a multitude of buildings for which no ancient precedents exist; how is he to treat them? Suppose, for example, he is planning a large church, say for 1,500 people, and suppose his clients are so unreasonable as to wish all these people to be placed in sight and hearing of the service, how is he to effect this at moderate cost with architecture worthy of the name? Here alone is a problem, to begin with, which

one man's lifetime would be too short to solve completely. Here is not only an opening, but an urgent need for originality: a case where originality is not merely desirable but absolutely indispensable. And what sort of treatment does it meet with? Nineteen times out of twenty, the problem is absolutely ignored—there is not a single step taken towards its solution. Either convenience alone is attended to, and the result is a "preaching-shed," disguised with a lot of vulgar finery; or art is the one thing followed, and the product is a beautiful church with no fault except sheer unfitness for its purpose. The architect, perhaps, has introduced much novelty into the carving of the capitals; his window tracery is singular and noteworthy; he has even brought from the Continent a tower and spire of extraordinary quaintness; but where the design called aloud for original thought—in its general planning and construction—he has not an idea to give us. Much the same is it with other buildings for public assembly. How should they be treated, when above a very limited size, so as to be successful internally and externally? There are our concert-rooms, like Exeter Hall and St. James's Hall; if they are to be built without columns, how are we to treat them on the outside to make their wide roofs and awkward proportions endurable? If, on the other hand, they are to be built with columns, where can these columns be least objectionably placed, and how, if they are of iron, can they be satisfactorily treated? There are our theatres, the very centres of all that is architecturally false and hideous. How can we make them honest in construction, simple and natural in design, fit for their intended use, and yet capable of yielding a sufficient return for the money invested in them? For those who have the opportunity of dealing with it, here is another problem almost large enough by itself to satisfy one man's ambition. Then again, there are our large railway stations; each of them, in their present state, enough by itself to spoil the finest view into which it intrudes; each of them, like those at Cannon-street, Charing Cross, and St. Pancras, so monstrous in its size, so astonishing in its shapeless deformity, that the mind can fix on nothing else while such an abortion is visible. Is it enough to dot over the walls of such a thing with bits of Gothic detail, and to leave its chaotic mass untouched; to sing songs of triumph over the "wonderful success with which Mediæval principles have been applied to a railway terminus," when the very sight of it a mile off might have filled any Mediæval builder with horror? We are not complaining of Mr. Scott, who, in his department doubtless did what was possible at St. Pancras. What we maintain is, that general design, here as elsewhere, is the first thing that demands attention, though unfortunately the last thing that usually receives it. Is it really essential that these vast stations should be covered in one span? or are the pleas put forward only meant to reconcile the public to a frightful eyesore, and the shareholders to a needless and wasteful expense? Is not the fact at bottom this, that the average engineer cannot understand any greatness except that which is measurable in feet and inches, and thinks that to put up a wider roof than anybody else is to prove himself a greater man? In this case it might be better for all parties to let him satisfy his ambition elsewhere; to find him a piece of waste ground, and pay the cost of erecting on it one truss as wide as he could possibly contrive, and then, having immortalized himself in the only way he can conceive of, to let him act, in his practical works, with an eye to such trivial matters as economy and beauty. But, however this may be, the general arrangement and construction of our larger railway stations presents one of the chief architectural difficulties of the time—one that is none the less truly architectural because it is seldom an architect whose business it is to grapple with it. We might go on enumerating, did space allow, many more types of modern building, each of which is a problem by itself. But a little reflection will furnish our readers with the list, and we therefore pass on to a wider question. What should be the general character and expression of our town architecture? What sort of grand combined effect can be got out of all the diverse designs which make up a modern city, or is there no such effect to be produced at all? Is it possible for us all, working each in his own way, and for his own ends, to make up, notwithstanding, a perfect and harmonious whole, or must we go on, as now,

in discord and confusion, each work injuring other works, and being injured by them? We look abroad, at certain Mediæval cities, and at certain other newly built ones, and see that both, in different ways, have arrived at a grand combined result. The first have done it by picturesqueness and freedom—by bringing out the individuality of every separate building, and emphasizing it by adopting, in short, a vertical type for their street architecture. The second have done it by uniformity and stiffness—by suppressing individual character, by settling every height and width, and projection, according to unalterable rules, by taking up the horizontal principle and imposing it on every one, by obliterating the individual houses, and caring only for the general mass of buildings. Is there any prospect in England of getting the latter system enforced by law? Is it likely ever to be generally followed without such enforcement? and, if not, is not the opposite system the only practicable, even if not the only desirable one? Seeing that we cannot make our streets uniform, is not the only true course to make them picturesque? To answer such questions as these is to do something towards solving the problem of how to produce harmony in our town architecture; how, at last, to make our cities a grand whole filled with beautiful and harmonious parts, instead of a chaos of mutually destructive elements. And where they are answered, either one way or the other, a multitude of other questions suggest themselves. Suppose the uniform and horizontal type of street architecture is set aside as impossible for us. Suppose the opposite type, where every separate building is individualized, proves itself to be the only one on which we can gain any sort of combined result. The first step towards its adoption—towards the marking off of each design from the rest, can hardly fail to be the introduction of a certain verticality into the composition. The heavy cornice is the natural crowning member on the uniform and regular type; when every house is made to range in height, a long unbroken line of such cornices binds the line together into what may be made one grand perspective. But the steep roof or gable is the most attractive finish on the alternative system; standing out against the sky, it marks off, as nothing else can, where the strip of elevation which it belongs to begins and ends. In London, however, the Building Act binds us down, for warehouses, to a certain limit in pitch; and in private houses, rooms wholly in the roof find little favor. It is, therefore, a matter for consideration whether steep roofs are essential to a picturesque street architecture, and especially to one developed on a Gothic basis; whether we can overcome, in some cases, the practical objections to them, and in other cases, dispense with them altogether.

Descending further into detail, the modern architect is met by unsolved, or, as yet, but half solved problems at every step. We can here only indicate a few of them in the briefest manner. What, for instance, is he to make of wrought-iron girders? May he use them, say, to carry the wall above a shop front, and, if so, is he to show them or conceal them? If he shows them, how far can they be made to harmonize with the brick or stone arches in the rest of the elevation? What, again, is he to make of iron roofs, and how is he to make their wiry lines agree in any way with the broad wall surfaces on which they rest; and how is he to finish his iron work—by painting, or bronzing, or enamelling—so as best to bring out its metallic character? We could point to examples where something has been done towards answering each of these questions; but in the average of recent work they scarcely seem to have had a thought. Then, in a very different department, how is the London architect to protect his work from London smoke? Of course, if he feels that it is not worth protecting, and is satisfied with Bath stone and stock bricks, he escapes this problem. But, in the opposite case, what are the best materials to use, granite and marble, terra-cotta, or glazed bricks? And how should his design be modified to suit each of them? Next, having settled how to make his works smoke-proof, he may consider how to make them partially or wholly fire-proof. As far, at least, as the staircase is concerned, this ought to be done in every house—not, if we may trust Captain Shaw, with stone, but with some material that fire will no more break than burn. Then there are the questions of how to ventilate houses; how to warm them more thoroughly and less wastefully; how to get

the plumbers' work a litte nearer perfection, and at least to keep the water-pipes from bursting every frost; how to improve the design of a multitude of details, such as chimney-pieces, grates, and ironmongery; how to use sash-windows and plate-glass with good effect in a Gothic building, or what to substitute for them; how, in short, to adapt old styles to modern uses, and to bring into the field of architecture the waste and uncultivated deserts which now stretch all around and wait to be reclaimed. We do not pretend to have indicated a tithe of the problems which are pressing for attention. These, however, may be enough to show that there is no want of subjects just now for thought, and that the designer who wishes to be original is not obliged to concentrate his talents on the production of some new form of moulding or chamfer-stop.

TRAMWAYS FOR CITY STREETS.*

By JAMES A. WHITNEY, M.E.

Of city pavements now in use there is not one without some manifest advantage, and none without some drawback, the amelioration of which would be a great public benefit. On Broadway we have the firm Belgian, best of all in its capacity for resisting abrasion, but with its interstices forming inequalities in the surface which result in great wear and tear of vehicles, increased labor upon draught animals, and an almost unending uproar; for it must be remembered that a single omnibus or cart in passing over one mile of this pavement is subjected to more than 60,000 concussions, or in an ordinary day's travel of, say, 30 miles, to nearly 2,000,000. The noise of the Belgian pavement, and to a great extent the severity of the concussive action upon it, is done away with in pavements formed with wooden blocks, which also, in a considerable degree, especially with light loads, lessen the draught. But pavements of wood, although found in Chicago to endure for 8 or 9 years without relaying, are worn down at the rate of more than ½ in. per annum under the crushing impact of the traffic in New York. Attention is, therefore, very naturally turned to the possibility of securing, in a measure at least, the same advantageous characteristics combined with greater durability. Even the old cobble-stone, perhaps the worst of all in every respect, save the security of foothold for horses, is for this one merit still retained between the tracks of our street railways, and a hint of the manner in which the paving of city streets may be best fitted for the duty required of it is given by the custom common among cartmen of driving the horse between the rails with at least one wheel running upon the track. To provide a pavement which will afford the firmest grip for horseshoes, and at the same time the smoothest running way for wheels, would, as nearly as is possible, meet the requirements of ordinary vehicles in traffic and transit in the city streets. This for a brief period is said to have been realized by an enterprising omnibus company in London, who changed the gauge of their vehicles to correspond with that of the tramway then recently laid down in the English capital. In this case, however, the parties, although they succeeded in showing the utility of the iron wheelways constituted by the rails, were promptly estopped by an injunction from interfering with the exclusive right to the track vested in the tramway company.

Incread ease of draught and security to draught animals, as already intimated, are the two all-important essentials of a superior pavement. The former not only enables a given number of horses to draw a greater load at the same speed, or the same load at a more rapid rate, but, from the nature of the conditions necessary to secure this, also insures a diminution of noise and decreases the deterioration of rolling-stock. A good hold for the feet of horses manifestly permits the smoothness of the running way to be utilized to the utmost, either for speed or power applied to propulsion, and also avoids the great liability to sudden and serious loss from the slipping and falling of horses upon the pavement. We may

* Paper read before the New York Society of Practical Engineering, Jan. 18, 1871.

therefore here consider, first, the relative values of different kinds of pavement with reference to the economy of draught power; second, the varieties best adapted to provide the requisite foothold for the animals by which the power is furnished; and third and lastly, the most feasible method of combining the best examples of the two in the least costly manner, and with the least interference with pavements already approved as in actual use in our streets.

The resistance of roadways or pavements made of different materials, and according to various plans, has been the subject of very careful research, especially abroad, and the results attained come verified as the dicta of the most eminent English engineers. According to these, a tractive power, equal to 100 lbs., continuously exerted, will draw on a level road as follows: A common gravel, 15 cwt.; macadam, 2,700; granite pavement, 3,500; broken stone surface laid on an old flint road, 3,400; same on a rough stone pavement, 4,800; wood pavement, 5,475; a stone pavement of more than ordinary uniformity, 6,700; and a common iron railway track, 27,600 lbs.

Of these examples, the gravel road may be taken as an equivalent to an average country road in good weather, and is of no interest in this connection. The macadam, still used in suburban districts, but objectionable from the grinding of its surface into dust, need not, for the reason just indicated, be further considered here. The granite and stone pavements, as will be seen from the above data, gave results superior to the macadam as far as traction is concerned; but when laid in blocks possessed all the manifest defects of our present stone pavements; and when of broken stone, laid on sub-pavements or foundations, those inherent in the macadam. The wood, affording, when properly laid, the surest footing for horses, shows also very high merit in point of non-resistance to tractive force, but, as several times intimated in the present writing, fails in point of durability. This, a serious defect, can only be partially remedied by the most judicious selection of material and the greatest care in preparing and laying down the blocks. The permanence of wood pavement may, however, be measurably increased by causing the abrading action of the wheels to be received by the best of all materials for the running or permanent way of wheeled vehicles. In other words, by iron tramways laid flush with the street surface, and so constructed that, while affording projections to keep horses from slipping upon them, smooth longitudinal ways will be furnished for wheels to run upon. The advantage of this is evident when we recall the enormous disproportion between the weight drawn by a tractive force of 100 lbs., on an iron track, and that moved by the same power on any other of the various kinds of pavement previously herein specified. Estimated roughly, this difference is so great, that one pair of horses can draw a load over a smooth iron tramway, which, on an ordinary macadam or turnpike, would require from seven to nine pair of draught animals.

Reasoning *à priori* from the basis just presented, it would seem that the best results would be achieved by providing a street with iron tramways, preferably two, for travel in opposite directions, the portion of the surface not occupied by the tramway tracks to be covered with a wood pavement. This latter, nevertheless, would not be essential, and in most instances it would, doubtless, be desirable to leave the present pavement undisturbed, except so far as absolutely necessary in laying the tramways.

In the preceding remarks, the writer has set forth, in general terms, the elements of a new system of street improvement, and the principles upon which the same is based. It is the invention of Samuel D. Tillman, well known as Prof. of Technology in the American Institute, and Chairman of the Polytechnic Association. With regard to the precise manner in which the improvement is to be carried out in practice, the writer cannot do better than to quote, in brief space, Prof. Tillman's own description of its peculiar and essential features:

"Employing iron as the material for the wheel-ways or tramways, I would," he says, "cast it in hollow blocks, so as to be interlocked, and its face could be provided with a series of smooth raised surfaces, alternating with impressions or indentations; and the raised surfaces could be so arranged that the wheel would be constantly sustained on a true grade by rolling over one raised surface, which should touch the middle of the tire, or

rolling over two raised surfaces, which, either simultaneously or alternately, would give a bearing to the wheel-tire near its sides. The transverse depressions thus formed allow the toe-cork or fore part of a horseshoe to sink below the raised or grade surface, and by means of such surfaces the horse would find a sufficient bearing against which to exert the leverage of his foot. A pair of iron paths, each about 1 ft. wide, and placed 4½ ft. apart, would provide a tramway suitable for vehicles of various widths, embracing the pleasure carriage, cart, lumber-wagon, and omnibus, and a pathway for a pair of horses between such tracks. The tramway could be made of hollow cast-iron blocks, each about 1 ft. long, with a projection on one end and a recess on the other, so that when brought together and interlocked, the pressure on the edge of one block would be transferred to the centre of the next. Such blocks could be laid directly on pure sand, or be filled in from beneath with wood, and laid on a perfectly solid and smooth foundation. The tramway could also be constructed of longer wrought-iron or cast-iron plates, having longitudinal ribs or webs underneath to strengthen them; each resting securely, by means of spikes, on one-half of the top of a wooden post set in the ground, and reaching below the action of frost. This plan would give a permanent pathway for the wheel, independent of that for the horse, and also would be unaffected by any changes which the surrounding earth might undergo by the action of water or frost. The face of such tramway could be composed of alternating smooth elevations and depressions, of a series of narrow ribs running longitudinally, or of a smooth surface having on it one or more lines of elevations and depressions, so arranged as to provide a foothold for horses, and, when placed on the edges of the tramway, to allow wheels to pass obliquely over without sliding."

It will be seen that the precise means employed in carrying the system into practice may be modified in many ways, but those which are thought preferable are thus described: each block is formed with two lateral or wing-like portions and a central and tongue-like portion in such a way that when fitted in line with each other the central tongue of one will fit between the wings of the other. These mutually support each other against superincumbent pressure, even when exerted at the edges of the blocks. This support is, furthermore, aided in a degree by lugs, provided in such manner as to jut into recesses or seats suitably arranged in the edges of the adjoining block. The upper surface of each block is grooved in such a way as to afford a foothold for horses, and at the same time, from the disposition of the grooves and of the raised surfaces between, furnish a bearing which shall be continuous upon some part of the periphery of the wheel passing over the same. The under side of each block is made of somewhat cellular form by longitudinal and transverse partitions, which constitute braces to give the requisite strength against vertical pressure, and also by their hold upon the sand, concrete, or other foundation, to prevent lateral displacement of the track. It is also proposed by the inventor to apply the same system of iron paving-blocks to the construction of pavements covering the entire surface of the street in cases where a pavement of such character is preferred.

Such, we remark in closing, are the essential features of an improvement by which it is proposed, at a fraction of the cost of any kind of pavement in use, to increase its utility many times by diminishing the power of draught required in moving vehicles through the street, and also to promote the greater permanence of the pavement itself, by causing the abrading action of the wheels to be received by the smooth and comparatively indestructible metal, instead of by granulating stone or soft or slowly decaying wood.

THE Pacific Steam Navigation Company, whose vessels run direct between Liverpool and the West Coast of South America, are providing their new steamers with Yarrow and Hedley's screw launches, in order to reduce the time occupied at the ports touched at, by keeping up a rapid communication with the shore.

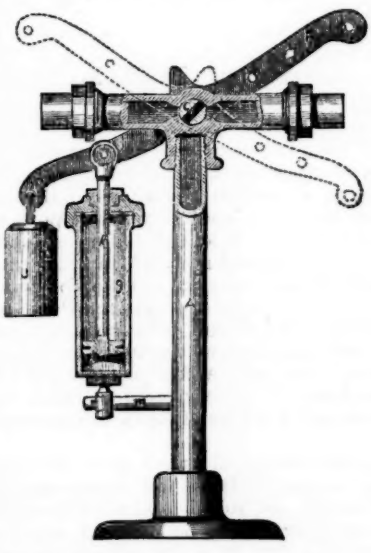
A MANUFACTORY of locomotives in Vienna has undertaken to furnish 80 locomotives on an order from Strasbourg.

IMPROVED METHOD OF REGULATING THE OPENING AND CLOSING OF COCKS.

From "The Mechanics' Magazine."

The principal object of this invention, by Mr. T. Penn, of Westbury street, Clapham, is to regulate the closing of water-closet and other cocks to give time for a certain quantity of water or fluid to flow through the cock from the time it commences to close until it is entirely shut off, at the same time preventing the cock from being injured by suddenly jerking it open; this is accomplished by affixing a suitable lever to the shank or stem of the cock made to extend out on both sides of it; to one end of this lever is attached a rod of brass furnished with a piston on the opposite end of the rod, and made to work in a tube or small cylinder of oil or other fluid, closed at one end and furnished with a screwed cap or cover at the other, through which the piston rod works; this cap is provided with a stuffing-box to make a joint around the rod. The piston is furnished with a small hole for the passage of the oil or fluid from one end of the cylinder to the other. The ease with which the cock opens or closes will depend upon the size of the hole in the piston for allowing the oil to pass from one end of the cylinder to the other when the cock is being opened or closed. The cock is opened by moving the opposite or same end of the lever to which the piston is attached, and may be worked or moved through the medium of bell cranks, rods, or cords and pulleys, or by taking hold of the lever direct. The passage of the oil from one end of the cylinder to the other through the openings in the piston will prevent it from being suddenly jerked open owing to the resistance given by the oil; a weight is attached to the end of the lever to which the piston is affixed for closing the cock by pulling the lever down; the size of the weight is regulated to suit the time in which the cock is to be closed. The lever to which the weight is suspended is provided with holes or notches for hanging the weight upon it at the proper point to get the required power for closing the cock at the proper time.

This improvement is particularly applicable to cocks employed in connection with water-closets, which can be regulated to give ample time for the water to flow after the pan is up to hermetically seal it; they can be fixed and worked in any position, and arranged without being connected to seat to interfere with its being removed for repairing the closet, or other purposes. The cylinder of oil or fluid in which the piston works is affixed to a bracket or standard placed in any suitable position for connecting the piston to the lever on the cock stem, and connected with lever and bracket so that the cylinder will accommodate itself to any position to suit the working of the lever. If desired, instead of making a hole through the piston for the passage of the



oil or other fluid, the piston may be made slightly smaller than the cylinder or tube for allowing the oil or other fluid to pass from one end of the cylinder to the other for giving resistance in opening and closing the cock for the purposes before stated.

Fig. 1 represents a cock mounted on a standard partly shown in section, and a sectional view of the oil cylinder.

A is a standard, to the top of which the

stock B of the cock is attached, as represented. C is the cock to which is attached the cross-lever E F; to the E end of the lever is attached the weight J, for drawing the cock close or shutting off the supply of water; to the same end of the lever is attached a piston rod *k*, working in the cylinder *g* through a stuffing-box, as represented; this cylinder will be filled with oil or other fluid if desired; the lower end of the rod *k* is furnished with a piston *f*, through which is made a suitable sized hole *h*, for allowing the oil in the cylinder to pass through it to regulate the closing of the cock; the piston *f* has a groove around its circumference for receiving a ring of leather or any other suitable substance for packing purposes; *m* is a support attached to and projecting from the standard A for carrying the cylinder *g*; the cylinder is so attached to this stem that it takes any position to suit the working of the lever E F. The cock is represented closed, and in order to open it, the E end of the lever may be drawn up by any suitable handle, rod, or cord, for working the same, or by drawing the F end of the lever down until it reaches the position denoted by the dotted lines in Fig. 1, when the cock will be full open for the passage of water, as described by the darts. The cock is then closed by the weight J pulling the lever down, which in the meantime forces the piston *f* to the lower end of the cylinder; the movement of the piston downwards is regulated by the resistance of the oil in the cylinder passing through the opening *h*, in the piston *f*; the time the cock C is kept open will depend on the size of the hole *h* for the passage of the oil, the larger the hole is the sooner the cock will close; the proper diameter of it will have to be ascertained by practice, for the various size cocks and quantity of water to be discharged in a given time.

ROLLING AND SWING BRIDGES.

From "The Artizan."

It not unfrequently occurs that it is required to erect a bridge across a river, or estuary, where the conditions of the locality render it necessary that a portion of the bridge should admit of being opened, or temporarily removed, in order that shipping may pass it, and the construction of such a bridge calls for the most careful consideration, both in the designing and execution of the work; hence we propose to offer a few remarks on the principles of these structures, such remarks being chiefly of a practical character.

There are several ways in which a bridge may be opened: thus the roadway may be withdrawn, or rolled backward towards the land, or it may be caused to revolve upon a centre, thus altering its position from being at right angles to the direction of the stream for one parallel to the same, or it may be caused to rise vertically about a centre fixed upon the pier. Of these three classes of bridges, the first is termed a rolling bridge, the second a swing bridge, and the third a bascule bridge; and the question to be determined is, which description of structure is best suited for the work set out for it.

The desiderata in opening bridges are, durability of parts, rapidity in opening and closing the bridge, and minimum of force required to effect the same. The importance of the first point is rendered more distinct by comparing an opening bridge with one which is permanent in its position. In the former case it is usually absolutely necessary that the bridge should, during certain periods in the day, be open, to allow the continuance of traffic on the river or estuary which it spans; hence if the working gear be out of order, so that the structure cannot be readily opened and closed, it must be kept open until it is again in a position to work with ease; therefore, while undergoing repairs, it is useless as a bridge, if those repairs are being made upon the moving gear. Rapidity in opening and closing the structure is very necessary, in order to reduce the loss of time due to stoppage of traffic to a minimum, for it must constantly occur that either the land traffic is stopped to accommodate that on the water, or *vice versa*.

The third requirement refers to the amount of force requisite to put and maintain the bridge in motion while open-

ing and closing, and, as a matter of course, the less power required, the simpler will the machinery be; the cost of working and wear and tear being proportionately small, hence the liability to derangement of the working parts is also small.

We will now proceed to consider *seriatim* the different descriptions of opening bridges, to which we have above referred, commencing with the rolling bridge.

The rolling span of an opening bridge is so arranged, that, when requisite, it can be wheeled or rolled back in a line parallel to the direction of the length of the bridge, so as to pass over or under another portion of the structure, or on to the land, thus leaving the space clear which it occupied when resting on its piers, and doing duty as a bridge. In such cases, the structure will usually be made to move upon four or more rollers, two of which are fixed to the shore end of the rolling girder, and, like ordinary carriage wheels, travel upon rails, while the others are supported in fixed frames or pedestals, the girders of the bridge resting upon them and passing over them, while rolling back and forward. To this description of structure there are many very grave objections, objections which theory will fail to discover, although after they are rendered conspicuous by practical experience, the defects giving rise to them may be accounted for by reasoning on the conditions under which these masses of matter are required to be put into motion. In the first place, it will be observed that there is a very great load on each roller, especially when we find only four rollers to sustain the entire weight of the bridge. Assume, for instance, such a work to weigh about 100 ons, which would correspond for a railway bridge to about a 70 ft. span, then there will be 25 tons weight on each roller carrying the bridge, and from the form of the bridge and its mode of motion, its progress is necessarily unsteady from its own vibration, which is increased by any inequalities of the surface upon which it runs, and also by starting or jerking of the propelling machinery.

As we have above stated, a part of the bridge must be allowed to rest on rollers in fixed pedestals, hence the lower surfaces of the bottom flanges of the girders are those upon which the rollers revolve, and any unevenness in such surfaces must very materially add to the amount of force required to keep the structure in motion, and if the flange be curved, it will of necessity involve the addition of extra force, either when opening or shutting, to propel it up the incline, produced by its own curvature. Moreover, a brief consideration will show us that such a curvature in the girders of a bridge cannot possibly be avoided, for if we make the bridge with a dead plane surface to its bottom flanges, it will deflect with its own weight; and even if we allow, for the sake of argument, that the bridge could be made with such a "camber" that its own weight will exactly bring it down to a straight line when on its bearings, then again whilst in the act of rolling its deflection would vary, for the distances of the points of support must vary, the rollers supporting the ends of the girders being fixed to and travelling with it, whilst the others retain their positions in relation to the fixed piers, so that when the rolling span is first started from its fixed bearings it has a long overhang, and there is a short distance or length of span between the fixed and travelling rollers; then as the bridge progresses in opening, this length of span increases, accompanied by the decrease of overhang, and a corresponding change occurs in the form of the girder. A similar but obverse change of form occurs in closing the bridge. This, then shows that there is a cause which cannot be obviated, always giving rise to excessive resistance to motion on the part of rolling bridges, which, we may observe, is much aggravated by the changes produced in a bridge by the vibratory effects of passing loads, and more especially of railway trains. The extent to which these disturbing causes affect rolling bridges may appear somewhat astonishing to those who have not been much acquainted with them in a practical sense, but when we observe serious mistakes in calculations connected with such matters, we look closely for the causes, and they often lie nearer the surface than might have been anticipated. To bring the matter more clearly forward, we will have recourse to figures obtained from actual trials. The first point to be determined is the amount of tractive force required to move the bridge; here it might seem that railway practice should furnish us with the requisite data; but, to be on the safe side,

we will allow a tractive force of 20 lbs. per ton of load; then for this we have, taking the rolling span of the bridge as weighing 100 tons, $100 \times 20 = 2{,}000$ lbs., or say roughly, 1 ton. This would be moderate enough, but we find in practice it sometimes requires three or four times as much, and in one instance there was actually six times the calculated tractive force applied to a rolling bridge before it would move, and then it went but slowly and spasmodically, notwithstanding that the bridge was well constructed and carefully erected. The excess of force requisite to propel the bridge was, of course, absorbed in overcoming those obstacles to motion, to which we have referred above.

Under these circumstances it wou'd seem that where they can be avoided it is exceedingly unwise to construct a rolling bridge, there being so many objections to it; but, of course, where the only available room lies in the line of the bridge, there is no option, and this class of work must be had recourse to.

The next bridge to which we shall refer is that on the "bascule" principle, being that which opens upward, as it were, like a box lid on hinges. This kind of structure answers passably well for small light spans, but when large, is objectionable on account of the power required to raise the weight, and also on account of the resistance of the wind to any opposite movement of a large surface against it.

The last arrangement to which we desire to call attention is that which has given the greatest satisfaction in practice, viz., the swing bridge, which opens by turning sideways, moving from its normal position across the stream to one parallel, or nearly so, to its direction. In this arrangement the bridge revolves upon a turn-table similar in construction to those used on railways, and is, of course, properly balanced, so that its weight may be duly distributed on the working parts of the turn-table.

By adopting the swing bridge, to avoid those great resistances to movement which are so fatal to practical utility of the rolling bridge, there is no tractive force required to produce actual removal of any portion of the structure, in the strict sense of the term; for the centre of gravity of the opening span, or swing portion of the bridge, remains unmoved. It is located, if properly balanced, in the centre of the turn-table when the bridge is closed, and it occupies the same position when it is opened; there has, consequently, been no actual transference of weight from one site to another, and the only resistance which has to be overcome is that due to the friction of the rollers in the turn-table, and the centre upon which the bridge rests; and that this may be reduced to a minimum is evident, from the fact that at the present time there are many turn-tables in actual use, which, when loaded with 60 tons, in addition to their own weight, are easily caused to revolve by one man acting at a distance of 25 ft. from the centre. Thus it is evident, that by improving the turn-table of swing bridges, we may fairly anticipate getting a structure as perfect as is practically possible to employ, where it is necessary that a bridge should open and shut; and in this direction we should strongly advise those contemplating the erection of such works to turn their thoughts, as the rolling bridge has in every case in which it has been used, proved a comparative failure, whereas swing bridges have generally served their purpose well, and the superiority of the latter evidently does not rest upon perfection of workmanship, but is due to accuracy of principle.

THE trunnion piece of the fourth 35-ton naval gun was forged in the Royal Gun Factories lately, the mass weighing upwards of 10 tons, being manipulated with great facility under the 12-ton Nasmith steam hammer. The magnitude of the operation will be better understood by the fact that the tongs used to wield the heat are 15 tons in weight. Twelve of these great guns are in course of manufacture, and the department has received an order for twenty 25-ton guns of 11-in. bore, similar to the half-dozen which were proved at the butts lately with 600 lbs. projectiles.

MR. AYRTON states that none of the methods used for preserving the stone of the Houses of Parliament has been completely successful, but that of Mr. Szerelmy has answered best. Further experiments are being made under scientific direction, to prevent the further decay of the stone, and it is hoped they will be successful.

THE CORROSION OF IRON.*

Formerly it was assumed that iron was subject to rapid corrosion when immersed in water, or exposed to the alternations of the water and the atmosphere, and the every-day experience of constructors seemed to confirm this opinion. Wrought-iron bolts in wooden dams and similar places and in works wholly under water, frequently rapidly oxidize. Cast-iron water-pipes in city streets are frequently found greatly corroded; and cannon and shot immersed in sea-water for half a century, and sometimes less, have been found with the mass of metal entirely changed from iron into plumbago, or deeply pitted by oxidation.

During the earlier discussions of the subject, the inquirer was frequently staggered in his belief in the generally received opinions, by finding both wrought and cast iron which had been immersed many years but slightly oxidated, and wholly unchanged in its structure.

The cannon of the "Royal George," which had been submerged half a century, when first taken out were so soft that the metal could be cut with a knife, but immediately hardened on exposure to the air, and were again fired. Some muskets and cannon, sunk in lakes Erie and Ontario during the war of 1812, were, forty years afterward, found to be but slightly rusted.

An iron steamer, the "Aaron Manby," which was launched in 1822, and kept in constant use for twenty years, was carefully examined, and no signs of corrosion found; and, ten years later, it is stated that she had required but small repairs for the whole period.

William Fairbairn also cites many cases where iron ships, which had been 10 to 15 years in salt water, showed no corrosion.

This subject was much discussed in England in 1850, and the unexpected absence of corrosion in wrought-iron ships, even on the interior surfaces and iron parts, was then attributed to the vibration of the metal, as was noticed on comparing the amount of the corrosion of railway bars in the track with those laid outside of it.

Plumbago was obtained from cast iron immersed in acidulated water in 1822, and 40 years later Dr. Calvert produced the same result by placing it in sea and foul water.

A dozen years earlier, Mr. Mallett reported his well-known experiments on the corrosion of different kinds of iron in pure and foul atmospheres, and in clear, foul, acidulated, and salt waters, and arrived at the following general conclusions:

That iron exposed to water holding air in combination corrodes on the surface either uniformly or in places, by rust or by the conversion of the iron into plumbago, and that corrosion depends upon the want of homogeneousness of the surface, or in its density or hardness, or in the combination of the carbon with the iron.

This subject was very thoroughly discussed by some of the most eminent engineers of the London Society in 1862, and numerous cases were cited both of corrosion and its absence in iron under water, and the causes explained.

The examples then stated, and numerous others, showed that cast-iron of a particular description corroded rapidly, or changed its structure, by a few years' immerson in foul or salt water, while other irons were entirely unaffected when exposed in the same way for 20, 30, and 40 years.

In the same structure, as in the case of the iron gates of the Sheerness Dock, three pairs of gates had resisted the action of salt water for 40 years, and a portion of the fourth pair, put in several years later, had been much softened and injured by its exposure.

Several of the leading engineers instanced numerous cases of square cast-iron piles, standing partly in and partly out of salt water, and a portion alternately wet and dry at each tide, which, after periods of 18, 24, and 31 years, and intermediate periods, showed no signs whatever of corrosion or change—"the square angles of the iron were as sharp as when they left the foundry."

Mr. Simpson, the past president, said that in his practice he used great care in the selection of the iron, and such iron was practically incorrosive.

* From a paper read before the American Society of Civil Engineers by the Hon. Wm. J. McAlpine, C.E.

The members stated, that wherever this corrosion or decomposition had occurred, it was wholly due to the quality of the iron. The engineer has, therefore, only to select that of a proper quality to insure durability.

My own experience and examinations, so far as they reach, confirm these opinions.

Cast iron, to resist corrosion to its greatest extent, should be as hard as the case will admit, of an even, close grain, and with the carbon combined and not in the form of graphite. Impure, soft foundry iron will corrode rapidly; close-grained gray iron, of an even texture, will resist corrosion in the most exposed places without sensible injury, and white iron of good quality may, for all practical purposes, be considered as imperishable in such situations.

Care should also be taken not to place iron in contact with other metals, so as to produce galvanic action.

It is well known that many cast-iron water mains have corroded greatly, not only externally but internally. In the latter case, the oxidation sometimes takes the tubercular form, where the rust is collected and aggregated in hard knobs.

In the early manufacture of water-pipes, they were often made from the worst quality of metal; it could hardly be called iron, but was a composition of cinders, sand, scoria, and iron of the softest kind, loose-grained, and in large crystals; indeed, precisely such a mixture as would offer the least resistance to corrosion.

Water-pipes placed in the streets of a city in earth alternately wet and dry, and saturated with mephitic gases from sewers and gas-pipes, are exposed to corrosion, more than under almost any other circumstances, and, if made of the material just stated, will be destroyed, where those of a proper quality of metal would endure a very long time. The internal corrosion, however, where the iron is exposed only to the action of pure water and a small amount of air in combination, will not occur to any appreciable degree, if the iron is of the proper quality.

The strength of cast-iron pipes, of the usual thickness, is so far beyond the pressure of the water and occasional percussions, that the manufacturers seem to think that the weakest metal will answer; and the engineers have not yet, in their specifications and inspections, required enough care in the selection of the metal best calculated to withstand corrosion.

INCRUSTATION IN STEAM BOILERS.

From "Engineering."

At a recent meeting of the Institution of Mechanical Engineers, a paper was read "On Whittle's Plan for Preventing Deposit and Incrustation in Steam Boilers," by Mr. George Addenbrooke, of Darlaston. The object of this plan is both to free boilers entirely from incrustation, and also to render harmless the impurities contained in the water, and prevent them from so thickening the water in contact with the heating surface of the boiler plates as to interfere with the due escape of the steam generated. This object is accomplished in a ready, inexpensive, and effectual manner, by placing loosely inside the boiler a lining composed of thin iron plates, extending over the entire heating surface of the boiler nearly up to the ordinary water level, with a uniform space of a few inches left between the boiler plates and the lining, for the circulation of the water. In the bottom of the lining are made openings, or a single long slot, round the edges of which the lining plates are turned up to some height, so as to prevent the mud that collects inside the lining from passing out through the openings with the circulation of the water. The effect of adding the lining inside any boiler is that a very active circulation of the water is produced; the water in the narrow space between the lining and the boiler plates becomes heated by contact with the heating surface of the plates, and forms a continued rising current, which passes over into the interior of the lining, carrying with it all the earthy matter that has been precipitated by the evaporation of the water. In the comparatively quiescent water inside the lining, this earthy precipitate then settles down to the bottom of the lining, where it remains

harmless in the form of soft mud, which never comes in contact with any part of the boiler heating surface, and is got rid of by blowing off at regular intervals, as it accumulates. The lining has thus the effect of separating the mud from the water, and rendering it harmless by simply mechanical means; but in the case of using chemical means, by employing boiler "compositions," the mud is dissolved, and continues mixed up throughout the water, which consequently becomes so much thickened as to cause injury to the boiler by overheating of the plates. The uniform space between the lining and the boiler plates is preserved by short studs at suitable intervals, upon which the lining plates are cottered, and any portion of the lining can readily be removed, whenever desired, for the purpose of examining the boiler plates at any part. Not only does the rapid circulation of the water over the heating surfaces prevent the formation of any incrustation upon the boiler plates, even when using very bad water, but in boilers previously incrusted with a considerable thickness of scale, the application of the lining has resulted in the gradual and complete removal of the incrustation, the scale being washed over in fragments into the inside of the lining. Some of the boilers fitted with this lining have purposely been kept in constant work, day and night, for more than two months, with feed water containing a large proportion of earthy matter, and without blowing off; and on subsequent examination the boiler plates have been found clean and free from incrustation, while a large accumulation of mud was deposited in the interior of the lining, so much in excess of the quantity of mud to be removed from an ordinary boiler as to prove clearly the value of the lining in separating the deposit from the water. Considerable economy of fuel is found to result from the more perfect communication of heat to the water in the boiler, consequent upon the clean heating surface, and the continuous active circulation effected by the lining. Specimens were exhibited of the soft mud collected in the lining in different boilers, and of the hard scale formed upon the surface of the plates in the same boilers previous to the application of the lining.

CENTRING.

From "The Mechanics' Magazine."

In the present age of engineering many of our permanent structures require during the progress of erection the aid of a temporary support, which, except for the nature of the materials employed in the two cases, does not very much differ from the work of construction with which it is for a time intimately connected. Any one who bestowed the most cursory attention upon the temporary works which for three or four years existed at Blackfriars, is aware that more material was used in them than would have sufficed to build a bridge over the Thames. According to the character of the temporary support, so is it named. The term centring originally and strictly applied only to arch bridges, but in its wider signification it is employed to designate a variety of staging, scaffolding, and timber supports. Centrings may be of all sizes, from the diminutive specimens used in building sewers and drains to the gigantic examples required for our large metropolitan bridges and station roofs. In the one case they consist solely of a few boards nailed together; in the other, they assume the dimensions and proportions of a large truss, demanding a considerable share of engineering skill and practical ability in order to effect their construction with safety and economy. Let us consider for a moment the case of the stone bridge over the Dee, near Chester. Its span is 200 ft., and, with one exception, it is the largest stone arch in the world. The weight that the centre for this bridge must have had to support, before the arch was finished, the key-stone driven in, and the wedges slacked, must have been enormous. There is an immense difference in this respect in a structure of stone and one of iron. In the former all is dead weight; the strength, in fact, lies in the weight. There is no assistance to be derived from taking advantage of the strains of compression and tension, in the manner in

which they can be provided for in the different members of an iron bridge or roof. In a word, there is no room for what is known as conversion of strain in a structure of stone. When the example consists of an iron bridge or an iron roof, there are various principles that may be adopted according to the especial circumstances of the case. Thus it is possible, by the selection of a particular design, to lighten the load that has to be borne by the centring. This is out of the question when stone arches have to be dealt with. The centres must then be constructed of the maximum strength, as not a particle of strain is taken by the permanent structure itself until the arch is keyed in. The designing of centring, and the timbering necessary to temporarily support tunnels, sewers, and bridges while their construction is in progress, is a particular branch of engineering. Many members of the profession who would be quite in their element in proportioning the scantlings and dimensions for a bridge over the Thames, would be quite at sea, to use a common phrase, if they were called upon to place *in situ* the timbering necessary to support the intended brick-work or masonry of a large sewer. On this account alone, a brief notice of the whole subject will not be without interest to our readers.

To commence with a familiar case, let us suppose that it is required to lay a sewer of moderate size in the ground at a depth of about 12 ft. or 14 ft. from the surface. If there is plenty of room on each side available for excavation, the trench or gullet is taken out pretty widely, and the quantity of timbering or shoring up necessary is reduced as much as possible. But, on the other hand, where from existing traffic or other causes, it becomes imperative to limit the lateral extent of the excavation to the minimum amount, the sides of the trench must be taken out "plumb," or as nearly so as the natural inclination of the ground wil admit. Abundance of examples in which this method is adopted are witnessed in the everlasting ripping out of the streets and main suburban thoroughfares of the metropolis. The trench is first taken out as neatly and cleanly as if the sides had been sawn through by a gigantic saw. They are then lined longitudinally with sheeting boards, and cross struts carried at proper intervals from one side to the other. At the proper level, where the arch of the sewer is to be turned, the centres are fixed. These are generally made for small examples in lengths, so that after a given length of the crown has been got in, the centre is removed, another length of arch turned, and so on until the whole work is completed. All the timber used in these instances can be made available for the next job of a similar character, as there is little or no damage done by bolt holes, straps, or other means of connection employed in larger and more pretentious works. The centres would not answer again unless the shape of the crown of the arch was the same, but they could be readily taken to pieces and put together again. One of the greatest difficulties to be overcome in the erection of all temporary staging and centring is to fix it in such a manner that, while it affords a firm support to the permanent work in progress, it shall not interfere with the men engaged in their various occupations. Thus, not only is there a considerable amount of skill required to design the supports so that they shall be strong enough for their purpose, but there is also a need of some ingenuity to arrange them so that they shall not prove an obstacle to the rapid progress of the operations. There is nothing more annoying to good experienced workmen than to find themselves hampered in every direction by the erection of posts, struts, and braces, which ought to have been placed in altogether different positions. Even in instances in which the staging is arranged in the best manner possible, it is not to be expected that the same amount of work will be got out of the men which they would perform were they excavating or building in the open. An extra price is invariably charged by contractors when the work to be done partakes of the nature already described, as men cannot get through their fair allowance of a day's work in narrow and restricted sites.

Passing on to those cases in which the staging and centring assume the proportions and forms of large temporary constructions, there are two particular examples which present themselves, and which are susceptible of separate treatment. In the one there is no obstacle to the free employment of a moderate amount

of strutting and bracing below the level of the soffit of the work. In the other the timbering must leave a perfectly unencumbered headway underneath. The strength of trussed centring will always be proportional to the depth, so that the more this dimension is reduced the weaker will the truss be. Fortunately this principle of construction admits of the reduction of depth below, the ordinary ratio of that dimension to the span being counterbalanced by the relative arrangement of the different members. Still the prohibition to give a certain depth to centring and staging has before now proved fatal to the adoption of particular types of bridges. It was so in the case of the original design for the "Britannia" Bridge over the Straits of Menai. The authorities, rightly or wrongly, insisted upon the waterway of the Straits being maintained intact during the erection of the bridge, which was an impossibility if any staging or centring were to be employed. The same duty is therefore frequently demanded of a centring as of a permanent structure which it serves for a time to support. It has to carry the load above, and leave as free a passage as possible below, and it becomes necessary to dispense with as much of the depth of the truss constituting the centring as can be done without. The centring used in the lining of portions of the tunnel lately completed under Mount Cenis furnishes a very good example of this method.

This plan is especially requisite in designing centring for tunnels, as the headway is always necessarily limited so as to reduce the excavation to a minimum. In spite of the almost universal application of iron to building purposes, timber still remains the favorite material for temporary works. It is true that iron centres have been used in a few instances, but they have made little or no progress as a substitute for the older material. In this respect, they are not nearly so far advanced as iron piles are with regard to those of wood. The fact is that timber is always to be obtained on very short notice, and can be cut and fitted so as to be adapted to different situations with far greater facility than any other constructive agent. After being in service in one particular work, it can be utilized again in another. Not exactly to the same advantage, for frequently it is so damaged and injured by bolts, spikes, and other means of fastenings, that it is only fit for being cut into small scantlings. However, even in this state it can be made useful, and can be sold for something. The magnitude of the work will be the real guide to the contractor in selecting his material for his temporary staging, centring, and details of a similar description.

An expedient was proposed with regard to centres at the time the agitation was strong respecting the Britannia Bridge, which displayed considerable skill and ingenuity. The principle is applicable in all cases when a bridge is to be erected over a river or portion of the sea, and in which the character of the situation forbids the construction *in situ* of any temporary supports. Let us suppose that the example is that of an arch of iron. The centre is first put up on a pontoon, and the arch built up over it, and secured in a perfectly firm and reliable manner. The pontoon is then floated to the site, and adjusted so that, by the falling of the tide, or by other mechanical means, the arch should rest on its bearings. The further sinking of the pontoon, carrying the centre with it, leaves the arch to itself, and, in a short time, the whole is floated away, and the waterway restored to its previous unimpeded condition. In designing a centre the chief objects to be kept in view are the employment of as few parts as possible, and the insuring that each component member does its proper share of duty. If timber be the material used, the connections should be all strongly made, and at the same time as few holes made in the wood as the nature of the design will permit of. This precaution is necessary for two reasons. In the first place, every bolt hole weakens the timber, and in the second, some regard must be had to the possibility of making use of it on a future occasion. Although, in one sense, it is no business of an engineer to design centres and scaffolding, otherwise than in a scientific manner, yet economy should always find a prominent place in his professional works. At the present day, estimates are scrutinized so exceedingly closely that it behooves every engineer to have a wholesome regard for economy in all details. Had space permitted, we should have drawn the atten-

tion of our readers to the methods adopted for striking and easing centring when used for the support of arches. This operation is accomplished gradually, or rather by successive small descents of the centres, until the permanent structure has taken a firm position upon its bearings. A great mistake, and one not unfrequently committed, is to strike the centres too speedily and too rapidly. Fatal accidents have happened when this error was indulged in; especially when the arches have been constructed of masonry or brick-work.

EXPERIMENTS ON THE OXIDATION OF IRON.*

By PROF. E. CRACE CALVERT, PH. D., F. R. S., ETC.

From "Nature."

Some two years since Sir Charles Fox inquired of me if I could give him the exact composition of iron rust, viz., the oxidation found on the surface of metallic iron. I replied that it was admitted by all chemists to be the hydrate of the sesquioxide of iron, containing a trace of ammonia; to this he answered that he had read several books on the subject, in which the statements referring to it differed, and from recent observations he had made, he doubted the correctness of the acknowledged composition of iron rust. He further stated that if he took a bar of rusted wrought iron, and put it in violent vibrations, by applying at one end the fall of a hammer, scales would be separated which did not appear to him to be the substance I had described. This conversation induced me to commence a series of experiments, which I shall now detail. I first carefully analyzed some specimens of iron rust, which were procured, as far as possible, from any source of contamination. Thus one of these samples was supplied to me by Sir Charles Fox, as taken from the outside of Conway Bridge, the other secured by myself at Llangollen, North Wales. These specimens gave the following results when submitted to analysis:

	Conway Bridge.	Llangollen.
Sesquioxide of iron	93.094	92.900
Protoxide of iron	5.810	6.177
Carbonate of iron	0.900	0.617
Silica	0.196	0.121
Ammonia	Trace	Trace
Carbonate of lime	——	0.295

These results clearly show the correctness of Sir Charles Fox's foresight, that the composition of the rust of iron is far more complicated than is stated in our text-books. Therefore the question may be asked, Is the oxidation of iron due to the direct action of the oxygen of the atmosphere, or to the decomposition of its aqueous vapor; or does the very small quantity of carbonic acid which it contains determine or intensify the oxidation of metallic iron? To reply to it, I have made a long series of experiments, extending over two years, and which I hope will throw some light on this very important question. Perfectly cleaned blades of steel and iron, having a gutta-percha mass at one end, were introduced in tubes which were placed over a mercury trough, and by a current of pure oxygen conducted to the top of the experimental tube; the atmosphere was displaced, and it was then easy to introduce into these tubes traces of moisture, carbonic acid, and ammonia. After a period of four months, the blades of iron so exposed gave the following results:

Dry Oxygen	No Oxidation.
Damp "	In 3 experiments, only 1 blade slightly oxidized.
Dry Carbonic Acid	No oxidation.
Damp " "	Slight appearance of a white precipitate of the iron, found to be carbonate of iron. Two only out of 6 experiments did not give these results.
Dry carbonic acid and oxygen	No oxidation.
Damp oxygen and carbonic acid	Oxidation most rapid, a few hours being sufficient. The blade assumed a dark green color which then turned brown ochre.
Dry oxygen and ammonia	No oxidation.
Damp " "	No oxidation.

* From a paper read before the Literary and Philosophical Society, London.

The above results prove that under the conditions described, pure and dry oxygen does not determine the oxidation of iron; that moist oxygen has only feeble action; dry or moist pure carbonic acid has no action, but that moist oxygen containing traces of carbonic acid acts most rapidly on iron, giving rise to protoxide of iron, then to carbonate of the same oxide, and lastly to a mixture of saline oxide and hydrate of the sesquioxide of iron. These facts tend to show that carbonic acid is the agent which determines the oxidation of iron, and justify me in assuming that it is the presence of carbonic acid in the atmosphere, and not its oxygen or its aqueous vapor, which determines the oxidation of iron in common air. Although this statement may be objected to at first sight, on the ground of the small amount of carbonic acid gas existing in the atmosphere, still we must bear in mind that a piece of iron, when exposed to asmospheric influences, comes in contact with large quantities of carbonic acid during 24 hours. These results appeared to me so interesting that I decided to institute several series of experiments. When perfectly clean blades of the best quality of commercial iron are placed in ordinary Manchester water, they rust with great facility, but if the water is previously well boiled and deprived of oxygen and carbonic acid, they will not rust for several weeks. Again, if a blade of the same metal is half immersed in a bottle containing equal volumes of pure distilled water and oxygen, that portion dipping in the water becomes rapidly covered with the hydrate of the peroxide of iron, whilst the upper part of the blade remains for weeks unoxidized; but if a blade be placed in a mixture of carbonic acid and oxygen, a very different chemical action ensues, as not only that portion of the blade dipping in the water is rapidly attacked, but the upper part of it immediately shows the result of chemical action, and also the subsequent chemical reactions are greatly modified by the presence of the carbonic acid. For in this case that portion of the blade is only covered with a film of carbon, together with a dark deposit composed of carbonate of the protoxide and hydrate of the sesquioxide. The fluid, instead of remaining clear, becomes turbid. These series of experiments substantiate the interesting fact observed—that carbonic acid *promotes* oxidation. A long series of experiments were also made to try and throw some light on the curious fact, first published by Berzelius, subsequently studied by other chemists, and well known to soap and alkali manufacturers, namely, that caustic alkalies prevent the oxidation of iron; my researches can be resumed as follows: (1) that the carbonates and bicarbonates of the alkalies possess the same property as their hydrates; and (2) that if an iron blade is half immersed in a solution of the above-mentioned carbonates, they exert such a preservative influence on that portion of the bar which is exposed to an atmosphere of common air (oxygen and carbonic acid), that it does not oxidize even after a period of two years. Similar results were obtained with sea water, to which had been added carbonates of potash and soda.

A SINGULAR accident occurred lately upon the West Hartlepool and Stockton branch of the North-Eastern Railway. The accident occurred to the passenger train leaving Ferryhill Junction at 6.5 P.M. for Stockton and West Hartlepool. After the division of the carriages at Norton Junction for these places, the Stockton portion pursued its journey southward; but when it arrived within a mile of its destination, the connecting-rod on the near side of the engine, suddenly snapping, was driven completely through the side of the boiler, so rending it as to allow the whole of the boiling water and steam to escape with a loud noise. The passengers were greatly alarmed, but no one was hurt.

THE returns of the quantities of gold obtained during 1870, in the gold fields of Nova Scotia, show an increased production of nearly 2,000 oz. The Albion mine produced 2,582 oz., and the Wellington mine 2,033 oz. The average yield of the colony is about 2 oz. of gold to the ton of ore; but McAlister mine is said to have yielded ore containing 71 oz. to the ton—the highest yield which has yet been obtained. In 1869 the quantity of gold produced was 17,868 oz.

REPORT ON THE ALLEN ENGINE.

From "The Engineering and Mining Journal."

We make the following extracts from the report of Wellington Lee, C. E., on the experiments conducted last November, for the purpose of ascertaining the economy and effective power of the Allen Engine, shown at the Exhibition of the American Institute.

It was determined to conduct two separate experiments; the first, for the purpose of ascertaining the consumption of coal per hour required for each 1-horse power of work done by the steam in the cylinder, as shown by the indicator diagrams; and the second, to ascertain the percentage of its indicated power that the engine was able to give off in useful effect.

The first of these experiments was conducted on the 3d of November, the engine driving the machinery of the Exhibition, increased, as far as possible, by the addition of two pumps and two large blowers. The next day the belt was removed, and the friction-brake was adjusted to the band-wheel of the engine for the second trial. It was not got in readiness for use, however, until the afternoon of the 5th, the closing day of the Fair, and was then found to be imperfect, and the hurried experiment that was tried showed only the necessity of a greater degree of care and thoroughness in the preparation than was then possible. After the close of the Exhibition, therefore, this trial was repeated, on the 18th and 19th days of November, under my personal supervision, in as public a manner as possible, and in the presence also of two of your number, and of four of the Managers of the Institute, and it was of a character calculated to inspire entire confidence in its results.

The two trials are described, and their results given separately.

DIMENSIONS AND PARTICULARS OF THE ENGINE.

Diameter of cylinder	16 in
Length of stroke	30 "
Revolutions per minute	125
Mean piston speed in ft. per min.	625
Foot lbs. of work done per min. in the cylinder, for each 1 lb. of mean pressure	125,662.5
Horse powers exerted in the cylinder, for each pound of mean pressure	3.808
Waste room in clearance and passages (cubic in)	248
Proportion added thereby to the piston displacement	.0411
Length added thereby to the stroke (in ins.)	1.23
Diameter of fly-wheel, in feet	9.
Weight of fly-wheel (pounds)	7,800

The engine has four valves, one for admission, and one for release at each end of the cylinder.

All the valves are driven from a link worked by one eccentric.

Total throw of eccentric, $2\frac{1}{2}$ in.

The admission valves are driven from the movable block, adjusted by the action of the governor.

The cut-off is variable, by this automatic action, from the commencement up to the half-stroke.

The exhaust valves are driven from a fixed point at the extremity of the link.

The valves are equilibrium slide valves.

Each admission valve opens four passages into one port. Aggregate length of four openings, 36 in. Width of each opening, when the steam is cut off at one-fourth of the stroke, $\frac{1}{4}$ of an in.; when cut off at half stroke, $\frac{2}{3}$ of an in.

Area of admission port, $9 \times 1\frac{1}{2}$ in. $= 13\frac{1}{2}$ sq. in.

Diameter of steam pipe 6 in.

Each exhaust valve opens two passages.

Area of exhaust port and passages, 20 sq. in.

Diameter of exhaust pipe, first length and elbow, 7 in.; remainder, 8 in.

The steam was released at 27.5 in. of the stroke, and compression began at 28 in. of the return stroke.

The cylinder was not steam jacketed, except on one side by the valve chest. On the exhaust side, a belt was interposed to protect it externally from the colder exhaust current. The cylinder was covered with boiler cement cased in wood lagging, except the steam chest, which was polished. The heads were double and polished. The engine was supplied with steam from the Allen boiler, which, by carrying the water at the middle of the horizontal pipes, superheated the steam in a slight degree.

The steam pipe was well covered with boiler cement.

FIRST TRIAL.

Following the precedent of last year, the water test only was used, and the consumption of coal is calculated, on the assumption that 1 lb. of coal burned evaporated 9 lbs. of water.*

The boiler was supplied from the tank which had been used for the boiler experiments, and which had a capacity of 25 cubic ft. It was filled by a 4-in. hose from the fire-plug on the avenue.

The time occupied in filling the tank was less than a minute, and during this operation the outlet to feed the pump was closed.

The volume of steam accounted for by the indicator has been ascertained as follows: the capacity of the cylinder at the instant of release was found by adding to the stroke (30 in.), the waste-room (1.23 in.), and subtracting the distance from the termination at which the exhaust port was opened (2.5 in.), giving a length of 28.73 in. The engine was credited for each stroke with this volume of steam at the terminal pressure (14.445 lbs.). It was then charged with the steam confined at the closing of the exhaust, which filled a length of (2 + 1.23) 3.23 in., at a density of 15.8 lbs.

The calculation made on this basis gives a consumption per hour of 43,963 cubic feet of steam at the pressure of 14.345 lbs. This volume, multiplied by the decimal .0358, the weight, in decimals of a pound, of 1 cubic ft. of steam at that pressure, gives 1,573.87 lbs. of water accounted for per hour, or 92.36 per cent. of the water evaporated.

It was made impossible for any water to enter the boiler, except that drawn from the tank, and all the steam generated, except that taken by the feed pump as hereafter mentioned, was worked through the engine.

The engine was run continuously for 11 hours, from 11 A. M. to 10 P. M., with two interruptions.

The first was at 2.30 P. M., for putting on a belt, and lasted only 2 min.; the second was at 6 o'clock, to permit an exhibitor to make some connections, and was protracted to 20 min. It was not expected, however, to be more than momentary, and we were hoping every minute to start again. The boiler was not thought of until it was heard blowing off with a pressure in the pipe of over 100 lbs., making it necessary to open also the $\frac{3}{4}$-in drain pipe from the main steam pipe. The exhibitors claimed that the loss of steam was certainly quite as much as the engine would have used if running, and as I found that the tank then emptying lasted a shorter time by 3 min. than the next one did, I have thought it right to allow the claim. No account of stoppages is, therefore, made.

No counter was employed, but the engine was timed occasionally, and was always at its full speed of 125 revolutions; if inexact at all, it was in excess of this speed.

A barometer was not used, the pressure of the atmosphere is assumed at 30.154 in. of mercury, or 14.8 lbs. on the sq. in.

The boiler had been supplied by a steam pump. For this trial, arrangements were made to feed it by a pump driven from the shaft, so that all the water sent into the boiler would be werked through the engine, as it was on trials last year. Unluckily, this pump gave out entirely on the morning of the trial, and the steam had to be used all day. No allowance is attempted to be made for this waste, but it seems proper to mention the fact that the engine worked under this slight disadvantage.

An important feature of this trial was the employment of steam slightly superheated. The mean temperature of the steam in the chest was 24.14° greater than that due to the pressure, and this chamber, extending the entire length of the cylinder, and around more than $\frac{1}{4}$th of its circumference, acted also as a steam jacket, and one in which no condensation could take place.

It is interesting and highly instructive to note, in the tables, how, as the degree of superheating was raised, and at the same time a greater weight of steam was admitted to the cylinder, the percentage of the water accounted for by the indicator increased, and the economy, shown by the time required to empty the tank, was improven.

SECOND TRIAL.

For the purpose of this trial, a friction brake was fitted to the band wheel of the engine, which was very suitable for this

* The evaporative duty of the boiler was in reality greater than this.

use, being 9 ft. in diameter by 26 in. width of face.

Each 1 lb. sustained at the brake represented 4,107 ft. lbs. of work done per min. Each 8.035 lbs. sustained required the exertion of 1 horse-power.

Each 30.6 lbs. sustained counterbalanced 1 lb. of mean pressure in the cylinder.

For the purpose of making the experiments more satisfactory, and of a character to expose their own errors or verify their own accuracy, five different weights were lifted, of 145 lbs., 374 lbs., 600 lbs., 800.5 lbs., and 10315 lbs., respectively. The first consisted of that portion of the weight of the apparatus itself, which preponderated on the rising side, and which was carefully ascertained.

A number of diagrams were taken on each of the five trials, and the pencil was allowed to pass over each diagram from 20 to 30 times. The trials on the 18th were only partial, and must be regarded as preliminary.

The diagrams were taken equally from each end of the cylinder, except the seventh one on the fifth trial. Those from the opposite ends were nearly, but not precisely, equal, which accounts for the more extreme differences appearing in the tables.

On each trial the diagrams from the same end ran nearly identical, although the relation between the pressures exerted on the opposite sides of the piston varied somewhat at different points of cut-off.

The diagrams do not show an equal proportional loss from friction, but are given as they are. By comparing the diagrams on the first and fifth trials, the increase of friction caused by the load is seen to be 3.5 per cent. That is, the difference between the diagrams exceeds, by this percentage, the difference between the weights sustained.

At the conclusion of the trial, the band was removed from the wheel, and the engine was run for the purpose of obtaining the fractional diagrams, with the result given in the tables.

Steam was supplied on this trial, as on the first one, by the Allen boiler, having 900 sq. ft. of heating surface, of which 730 ft. were below the water line, and 170 ft. above it. Steam was easily kept up while the engine was exerting 141.68 horse-powers.

To test the power of the engine, the steam-pressure was run down below 60 lbs., and diagrams were taken, with an initial pressure of from 53 to 56 lbs., cutting off at .45 of the stroke, and developing 141.68 indicated horse-powers. The pressure was then raised to 90 lbs., and diagrams were taken with an initial pressure of 85 lbs., cutting off at .23 of the stroke, and developing the same power.

The following tables are those given in the report, except that we have been compelled in some instances to reduce them to a mere statement of the average results obtained.

TABLE 1.

The Water Evaporated.

The water tank was emptied twelve times.

Time required to empty the Tank.	Weight of Water furnished to Tank.	Weight of Water which the diagrams account for.	Percentage of the Water accounted for.
11 hrs.	18,750 lbs.	17,304.7 lbs.	92.29

The twelfth tank was emptied a few minutes before 10 o'clock, but the water was then too high in the boiler, and when —at 10 o'clock—the engine was stopped, it had been reduced to the precise mark at which it stood at the start. About one-seventh of the water accounted for by the indicator during the last 65 minutes was derived from preceding tanks.

TABLE No. 2.

Capacity of Tank, in cubic feet.	25
Weight of one cubic foot of water (lbs)...	62 5
Pounds of water evaporated	18,750
Pounds of water evaporated per hour.....	1,704 5
Pounds of coal burned per hour.....	189.4
Mean pressure in the cylinder, above that required to neutralize the counter pressure (lbs. on the square inch)	17.345
Horse powers exerted for each 1 lb. of mean pressure.....	3.808
Effective indicated power (horse power)....	66.05
Coal burned per hour for each effective indicated horse power (lbs).....	2.868
Pressure of the atmosphere in lbs. on the square inch (assumed).....	14.8
Mean back pressure above that of the atmosphere in lbs. on the square inch.....	.983
Total mean pressure in cylinder, in lbs. on the square inch	33.128
Total work done by steam in cylinder (horse powers).....	126.15
Coal burned per hour for each gross horse power (lbs.).....	1.5
Proportion of work done by the steam that is reckoned as effective.....	.5236

TABLE No. 3

To Show the Cost of the Indicated Horse Power of the Engine.

	Pressure in the Steam Pipe by Gauge.	Temperature of Steam in Chest.	Degrees of Superheat.	Initial pressure.	Proportion of Stroke at which the Steam was cut off.	Mean pressure.	Terminal pressure.	Theoretical Terminal Pressure.	Excess of Ter. Pres. above Theoretical.	Average Back Pres. above atmosphere. (Indep't of Cushion.)
	lbs.	deg.	deg.	lbs.		lbs	lbs	lbs.	lbs.	lbs.
A	72.975	343.9	24.14	69.965	.11	17.345	—.455	—2.085	1.63	.983
B	73.25	344	23.88	71.1	.1	16.33	—0.51	—2 57	2.06	1.03

The figures given in the upper line (A) are from diagrams taken from the forward end of the cylinder, and those in the lower line (B) from the back end.

TABLE (4) A.

Work Done at the Brake.

	1st Trial.	2d Trial.	3d Trial.	4th Trial.	5th Trial.
Weight sustained	143 lbs.	374 lbs.	605 lbs.	800.5 lbs.	1031.5 lbs.
Foot pounds of Work done per Minute	587,301	1,536,018	2,4 4,735	3,287,653	4,236,370
Horse Powers developed	17.797	46.546	75.295	99.624	128,375
Lbs. of Mean Pressure in Cylinder required to be in Equilibrium	4.673	12.222	19.771	26.16	33.71

TABLE (4) B.

Power Exerted in the Cylinder.

	Pounds of Mean Pressure.				
General Average	7.14	14.76	21.97	28.55	37.207
Horse Powers exerted	27.19	56 2	83.66	108.72	141 68
Percentage of useful effect	65.45	82.8	90.	91 62	90.6

	Forward End of Cylinder.		Back End of Cylinder.		
Frictional Diagrams	No. 1.	No. 2.	No. 3.	No. 4.	Average
Mean Pressure	2.225 lbs.	2.2 lbs.	2.175 lbs.	2 1 lbs.	2.175 lbs.

The Mean Back Pressure above the Atmosphere Averaged .5 lb.

TABLE 5.

Comparison of the Results with those Obtained Last Year.

	Allen.	Corliss.	Babcock & Wilcox.
Diameter of cylinder (inches)	16.	16.13	16.
Area of cylinder (square inches)	201.06	204.25	201.06
Length of stroke (inches)	30.	42.	42.
Waste room adds to stroke (inches)	1 23	1 3	.63
Revolutions per minute	125.	60.344	60.273
Feet travelled by piston per minute	625.	422.4	421.9
Cubic feet displaced by piston per hour	52,344.	37,014.	35,900.
Pressure of steam in pipes (lbs.)	72.975	80.51	81.69
Initial pressure in cylinder (lbs.)	69.965	70.943	76 148
Proportion of stroke at which steam is cut off	.11	226	.189
Effective mean pressure (lbs.)	17.345	29 728	31.057
Effective horse powers exerted	66.05	76.579	78.792
Counter pressure above atmosphere (lbs.), see note 2	.5	.68	.8
Pressure of the atmosphere (lbs.)	14.8 (a'ssd)	14.8	15.043
Total mean pressure (lbs.)	33 128	45 208	46 9
Gross horse powers exerted	126.15	116.456	118.985
Proportion of total work done by steam in cylinder, that is reckoned as effective	.5236	.6622	.6575
Pressure at termination of stroke, relatively to that of the atmosphere (lbs.)	—.455	+5.178	+3.055
Total pressure at termination of stroke (lbs.)	14.345	20.	18.1
Weight of one cubic foot of saturated steam at the terminal pressure (lbs.)	.0358	.0487	.0447
Pounds of water evaporated per hour	1,704.5	1,995.547	2,007 746
Pounds of steam per hour, *by indicator*	1,573 87	1,815 723	1,595.496
Percentage of water accounted for by the indicator	92.36	90 99	79.47
Number of times the volume of steam is multiplied by expansion	6.3	4.3	5.
Ratio of gain by expansion	2.3	2.25	2.6
Pounds of coal per hour for each effective horse power	2.868	2.89	2.831
Pounds of coal per hour for each gross horse power.	1.5	1 9	1.87
Percentage of indicated power that was usefully exerted	91.11	90.23	87.2

From the foregoing tables it will be noticed :

I. The theoretical terminal pressure was ascertained by calculation from a point on the expansion curve after it was certain that the steam had been cut off—a method that insures accuracy.

II. During the friction brake experiments, when the steam was discharged under some pressure, the back pressure was observed to be much less than during the trials for economy. This was doubtless owing to the fact that in the former case the large body of steam in the exhaust pipe was put in motion at high velocity by the pressure at the instant of release, while in the latter it was inert, and so resisted the motion of the piston.

The difference was very marked, and when the steam was released at from 3 lbs. to 6 lbs. pressure, the back pressure could not be judged to exceed .5 of a pound. In comparing the results with those of last year, when the steam was released at about this pressure, the latter decimal must therefore be used.

III. The Allen Engine Works had requested that the engine should be loaded for the trial to the extent of at least 100 horse-powers, in order that the mean effective pressure in the cylinder should be as great, or nearly so, as it was in the engines tried last year. Efforts were made to provide this amount of resistance, but with very poor success. The diagrams show only 66.02 horse-powers exerted, requiring a mean effective pressure of only 17.345 lbs. against 29.728 in the Corliss, and 31.057 lbs. in the Babcock and Wilcox engines. No just comparison for economy can, therefore, be made, except by measuring the total work done by the steam in the cylinder in each case ; for, if the work done in overcoming the atmospheric resistance

were deducted alike in all the engines, then we would have only 52.36 per cent. of the total work done allowed to the Allen engine, and an average of 66 per cent. allowed to its competitors, as effective power, while in truth the work of the steam in overcoming the pressure of the atmosphere is precisely the same as if the resistance overcome was that of a pump or a saw-mill. To illustrate this by a more extreme case, let the mean effective pressure be only 5 lbs., making, with the atmosphere, a total pressure of 20 lbs., and let the coal burned be, as in this case, 1.5 lbs. per hour for each gross horse-power. Now, if the atmosphere is deducted, the consumption for each effective horse-power will be 6 lbs. per hour.

It is obvious that when the pressure differs so widely as in the present case, a comparison made after deducting the atmosphere would give a very enormous result.

The coal burned for the Allen engine, divided by 52.36 per cent. of the power exerted by the steam, gives a quotient that is just the mean of those obtained by dividing the coal burned for the Corliss and the Babcock & Wilcox engines by 66 per cent. of the power exerted in them ; and the coal burned in each case, divided by the total power exerted, shows a consumption for the Allen engine of 1.5 lbs. for horse power per hour, against a consumption of 1.87 lbs. for the Babcock & Wilcox engine, and of 1.9 lbs. for the Corliss engine.

This economy is believed to be without precedent, except in cases where steam has been expanded in two or more cylinders, and re-heated on the passage.

IV. The ratio of gain by expansion is ascertained by dividing the mean pressure through the stroke, which represents the work done, by the pressure at the termination of the stroke, which represents the steam consumed in doing it.

The gain of 2.3 by expansion shown in the Allen engine is perfectly correct, and consistent with the theoretical tables, as will appear, because, first, these tables make no account of waste room, and second, the terminal pressure or divisor is, on the diagrams, higher than the theoretical expansion calls for. In order to find both the point of cut-off and the mean pressure for any comparison of the diagram with the requirements of theory, the waste room must be regarded as forming a part of the piston displacement. In this case the steam was expanded to 6.3 times only, instead of 9 times its original volume.

It cannot be contended that the superior economy of the Allen engine is due to its working more expansively, as its gain from expansion was not materially different from that of the other engines.

V. At each stroke of the piston, 16,651.8 foot lbs. of work were done in the cylinder, involving a loss of 21.57 units of heat, or heat sufficient to raise the temperature of 1 lb. of water 21.57°. The weight of steam which entered the cylinder was .1136 of a lb., and it contained 138.8 units of heat. Of the 21.57 units of heat lost during the stroke, 9.38 units were lost before the closing of the port, and might have been restored directly from the boiler. The remainder, 12.19 units, were converted into work during the expansion. Of this amount, 2.78 units were supplied from heat set free by the expansion, leaving 9.41 units, which, if no other source of heat existed, must have been supplied by the condensation of nearly $\frac{1}{13}$th part of the steam. But about $\frac{1}{2}$ of the cylinder walls had a temperature equal to that of the steam in the chest, or 132° greater than that of the steam when expanded to the atmospheric pressure, and this surface was sufficient, at the rapid reciprocation employed, to impart to the steam, during its expansion, a very considerable amount of heat, and in this manner, without doubt, the heat converted into work was so far restored to the steam as to cause the indicator to account for the very large percentage of the water evaporated that is shown in Table 1.

VI. In stating the power given off by the Allen engine, in comparison with that given off by the Corliss & Babcock and Wilcox engines, it is necessary to have regard to the mean pressures exerted.

The mean effective pressure exerted in the latter engines averaged about 30 lbs. on the sq. in. of piston.

During one of the experiments with the friction brake, the mean effective pressure in the Allen engine was 28.55 lbs., and during another it was 37.207 lbs. It seems fair to take the mean of these

two as the comparative duty of this engine, which is thus fixed at 91.11 per cent. of the indicated power..

Finally, the performance of the Allen engine, it will be seen, exceeded that of the engines tried last year, both in its economy and in the proportion of its indicated power that was given off in useful effect, and also, what its high speed renders especially remarkable, in the proportion of the steam pressure in the pipe that was realized in the cylinder, and in the absence of back pressure. It ran also through the Fair, and on many of the days for 11 and 12 hrs. successively, without ever having a warm bearing.

The report is followed by the endorsement of the Judges, Messrs. Barnard, Sloan, and Weir, who witnessed the performances of the engine.

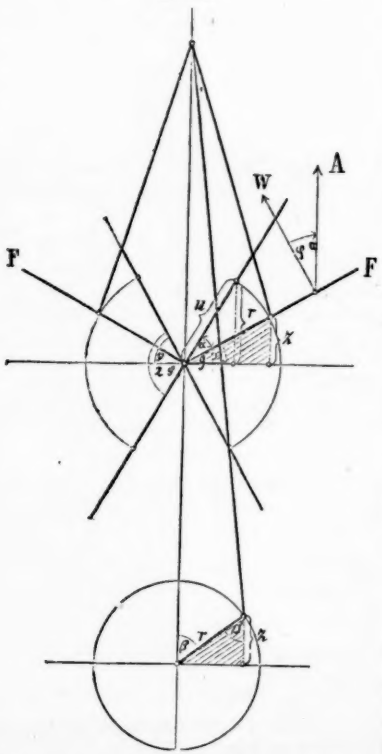
THE MECHANICS OF FLYING.

(*Continued from page* 351.)

6. DETERMINATION OF THE EQUATION OF CONDITION FOR HOVERING.

Suppose the flying apparatus has two wing-surfaces F, which can be moved by means of a wheel and axle. Let the

FIG. 5.



wheel revolve so as to depress the wings with the constant angular velocity ω_1, and to raise them with the constant angular velocity ω_2. Let the crank rod be very long, so that in calculation it may be assumed of infinite length. The force K acting at the centre of gravity is to be determined ; then its velocity can be found by integration.

$$K = A - G = W \operatorname{Cos}(-\alpha) - G.$$

The resistance depends on the velocity of the wings. Let

ω = angular velocity of wheel in metres.
α = the momentary inclination of wing surfaces at extreme position.
β = the corresponding angle of inclination to the vertical of the handle.
ϕ = half the stroke-angle.
r = length of handle.
u = distance of connection of rod from the centre of rotation of the wing surfaces.

Then from the hatched triangles in Fig. 5, we see

$$Z = u \operatorname{Sin}(\phi - \alpha) = r \operatorname{Cos}\beta.$$

But since

$$\frac{r}{u} = \operatorname{Sin}\phi,$$

we have

$$\operatorname{Sin}(\phi - \alpha) = \operatorname{Sin}\phi \operatorname{Cos}\beta \quad . \quad . \quad . \quad (1.)$$

and by differentiation

$$-\frac{\operatorname{Cos}(\phi - \alpha)\, d\alpha}{dt} = -\frac{\operatorname{Sin}\phi \operatorname{Sin}\beta\, d\beta}{dt}$$

$\frac{d\beta}{dt}$ is equal ω_1 the constant angular velocity, hence

$$\frac{d\alpha}{dt} = \omega_1 \operatorname{Sin}\phi \frac{\operatorname{Sin}\beta}{(\operatorname{Cos}\phi - \alpha)}.$$

From (1)

$$\operatorname{Sin}\beta = \sqrt{1 - \frac{\operatorname{Sin}^2(\phi - \alpha)}{\operatorname{Sin}^2\phi}}$$

and this value substituted gives

$$\frac{d\alpha}{dt} = \omega_1 \frac{\sqrt{\operatorname{Sin}^2\phi - \operatorname{Sin}^2(\phi - \alpha)}}{\operatorname{Cos}(\phi - \alpha)} \quad . \quad . \quad (2.)$$

The resistance of the two wing surfaces is

$$W = 2\zeta \frac{\gamma}{2g} F_1 n_1^2 \left(\frac{d a}{d t}\right)^2$$

and substituting for $\frac{d a}{d t}$,

$$W_1 = 2\zeta \frac{\gamma}{2g} F_1 n_1^2 \omega_1^2 \frac{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}{\mathrm{Cos}^2 (\phi - a)} \quad (3.)$$

and the buoyancy of both wing surfaces is

$$A_1 = W \mathrm{Cos} (\phi - a) = 2\zeta \frac{\gamma}{2g} F_1 n_1^2 \omega_1^2 \times \frac{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}{\mathrm{Cos}^2 (\phi - a)} \quad . \quad . \quad . \quad ((4.)$$

F_1 being the surface of a wing.

For the back stroke the wing surface changes to F_2. In birds it is diminished by the lapping of the feathers.

The constant angular velocity of the wheel is a_2, the radius of resistance $= n_2$, and the buoyancy is

$$A_2 = -2\zeta \frac{\gamma}{2g} F_2 n_2^2 \omega_2^2 \frac{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}{\mathrm{Cos} (\phi - a)} \quad (5.)$$

The acceleration of the centre of gravity during the downward stroke is

$$p = g \cdot \frac{A_1 - G}{G}$$

and substituting for A_1 from (4)

$$p = g \frac{2\zeta \cdot \frac{\gamma}{2g} F_1 n_1^2 \omega_1^2 [\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}{G \, \mathrm{Cos} (\phi - a} - g$$

But since

$$p = \frac{d v}{d t}$$

we obtain by integration between limits $t = 0$ and $t = t_1$ (down stroke).

$$v_1 - v_0 = \frac{2\zeta \cdot \frac{\gamma}{2g} \cdot F_1 n_1^2 \omega_1^2 g}{G} \int_{t=0}^{t=t_1} \frac{[\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)] \, dt}{\mathrm{Cos} (\phi - a)} - \int_{t=0}^{t=t_1} g \, dt$$

Substituting the value of $d t$ from (2)

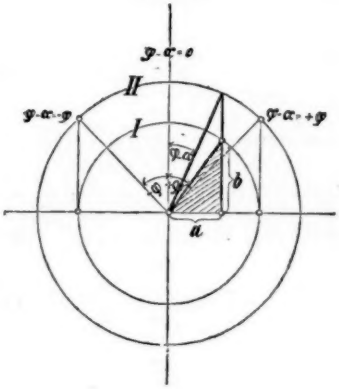
$$v_1 - v_0 = \frac{2\zeta \cdot \frac{\gamma}{2g} F_1 n_1^2 \omega_1^2 g}{G \omega_1} \int_{a=0}^{a=2\phi} \sqrt{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)} \, da - \int_{t=0}^{t=t_1} g \, dt \quad . \quad . \quad . \quad . \quad . \quad . \quad (6.)$$

DETERMINATION OF THE INTEGRAL.

$$\int_{a=0}^{a=2\phi} \sqrt{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)} \, d a.$$

This integral may be found approximately by construction. In Fig. 6 the

FIG. 6.



circle I is described with radius Sin ϕ; II, with the radius unity. In the hatched right angled triangle the hypothenuse = Sin ϕ; one side $= a$ Sin $(\phi - a)$; the other

$$b = \sqrt{\mathrm{Sin}^2 \phi - \mathrm{Sin}^2 (\phi - a)}$$

Multiplying the ordinate of the small circle I, by the corresponding differential of the arc $d a$ of the large circle II, and taking the sum, we obtain the desired integral.

If Sin ϕ is small, and consequently ϕ is also small, then between the limits

$$\phi - a = -\phi \text{ and } \phi - a = +\phi$$

$d a$ will differ little from $d x$; and as ϕ is small the value of the integral is equal to the surface of the semicircle of I.

$$\int_{a=0}^{a=2\phi} \sqrt{\mathrm{Sin}^2 \phi - \mathrm{Sin}_2 (\phi - a)} \, . \, d a = 2 \frac{\pi}{4} \mathrm{Sin}^2 \phi$$

if ϕ is small.

For $\phi = \frac{\pi}{2}$ (large stroke-angle) both circles coincide; and since from the hatched triangles we have

$$d a : dz = \mathrm{Sin} \phi : y$$

then

$$y \, d a = dx \, \mathrm{Sin} \phi \, .$$

therefore constant, and the surface

$$\int_{a=0}^{a=2} \sqrt{\text{Sin}^2\phi - \text{Sin}^2(\phi - a)}\, da$$

passes into the double surface of the square $\text{Sin}^2\phi$; therefore if ϕ is large

$$\int_{a=0}^{a=2\phi} \sqrt{\text{Sin}^2\phi - \text{Sin}^2(\phi - a)}\, da = 2\,\text{Sin}^2\phi$$

While ϕ increases from 0 to $\frac{\pi}{2}$ the value of this integral varies uniformly, hence there is always a mean value.

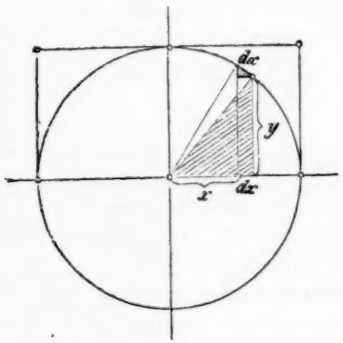
$$\frac{2\pi}{4} \sin^2\phi \text{ and } 2\,\text{Sin}^2\phi$$

and generally

$$\int_{a=0}^{a=2\phi} \sqrt{\text{Sin}^2\phi - \text{Sin}^2(\phi - a)}\, da = 2\,\text{Sin}^2\phi.\Phi \quad (7.)$$

in which Φ is a function of ϕ, which always has a mean value of $\frac{\pi}{4}$ and 1.

FIG. 7.



Substituting the value of this integral in (6) gives

$$v_1 - v_0 = \frac{2\zeta \cdot \frac{\gamma}{2g} F_1 n_1^2 \omega_1^2 g}{G\omega_1} 2\,\text{Sin}_2\,\phi.\Phi - g t_1 \quad (6a.)$$

for the back stroke

$$v_2 - v_1 = -\frac{2\zeta \cdot \frac{\gamma}{2g} F_2 n_2^2 \omega_2^2 g}{G\omega_2} 2\,\text{Sin}_2\,\phi\Phi - g t_2 \quad (6b.)$$

$$2\zeta \frac{\gamma}{2g} F_1 n_1^2 \omega_1^2 \text{Sin}^2\phi$$

is the maximum resistance of both winged surfaces (in mean position) during the down stroke. This we denote by $W_m^{\,1}$.

$$2\zeta \frac{\gamma}{2g} \cdot F_2 n_2^2 \omega_2^2 \text{Sin}^2\phi$$

is the maximum resistance of both surfaces during up-stroke, and is denoted by $W_m^{\,11}$, hence we have

$$V_1 - V_0 = \left[\frac{2 W_m^{\,1} \Phi}{G\omega_1} - t_1\right] \text{ and } V_2 - V_1 = -g\left[\frac{2 W_m^{\,11} \Phi}{G\omega_2} - t^2\right].$$

Instead of the angular velocity ω_1 and ω_2 the time of down-stroke and back stroke can be substituted. The path of a point in the handle at the distance 1 from the axis, during up or down stroke is π. Hence

$$\pi = t_1\,\omega_1 \text{ and } \pi = t_2\,\omega_2 \quad . \quad . \quad . \quad (8.)$$

Substituting

$$v_1 - v_0 = g t_1\left[\frac{2 W_m^{\,1} \Phi}{G\pi} - 1\right] \text{ and } v_2 - v_1 = -g\, t_2\left[\frac{2 W_m^{\,11} \Phi}{G\pi} + 1\right] \quad . \quad . \quad . \quad (9.)$$

For hovering

$$v_1 - v_0 = -v_2$$

hence

$$g t_1\left[\frac{2 W_m^{\,1} \Phi}{G\pi} - 1\right] = g\, t_2\left[\frac{2 W_m^{\,11} \Phi}{G\pi} + 1\right]$$

from which

$$W_m^{\,1} t_1 = W_m^{\,11} t_2 = \frac{(t_1 + t_2) G\pi}{2\Phi}$$

Putting

$$\frac{t_2}{t_1} = k, \quad \therefore \quad W_m^{\,1} - W_m^{\,11} k = \frac{(1+k) G\pi}{2\Phi} \quad . \quad (10)$$

This is the condition of floating or hovering. W_2 is always small compared with W_1; neglecting this we have for large stroke angle $\phi = 1$.

If $k=1$	$k=\frac{1}{2}$	$k=\frac{1}{3}$	$k=0$
$W_{m1}=\frac{1}{2}G$	$=\frac{3}{4}\pi G$	$=\frac{2}{3}\pi G$	$=\frac{1}{2}\pi G.$

Hence we see that the maximum resistance of the wings is great; and within practical limits may be taken as equal to twice the weight of the bird.

(7.)—DETERMINATION OF THE NUMBER OF STROKES.

The condition for hovering is equation (10.)

$$W_m^{\,1} - W_m^{\,11} k = \frac{(1+k) G\pi}{2\Phi}$$

in which

$$W_m^{\,1} 2\zeta = \frac{\gamma}{2g} F_1 n_1^2 \omega_1 \text{Sin}^2\phi =$$

$$2\zeta \frac{\gamma}{2g} F_1 n_1^2 \text{Sin}^2\phi \frac{\pi^2}{t_1^{\,2}}$$

and

$$W_m{}^{11} = 2\zeta \frac{\gamma}{2g} F_2 n_2{}^2 \omega_2{}^2 \operatorname{Sin}^2 \phi =$$

$$2\zeta \frac{\gamma}{2g} F^2 n_2{}^2 \operatorname{Sin} \phi \frac{\pi^2}{t_2{}^2}$$

This value substituted gives

$$2\zeta \frac{\gamma}{2g} \pi^2 \operatorname{Sin}^2 \phi \left[F_1 n_1{}^2 - \frac{F_2 n_2{}^2}{k_2} \right] = \frac{(t_1{}^2 1 + k) \pi G}{2 \Phi}$$

Hence

$$t_1 = \operatorname{Sin} \phi \sqrt{\frac{2\zeta \gamma \pi \Phi (F_1 k^2 n_1{}^2) - F_2 n_2{}^2}{g (1+\kappa) G k^2}} \quad (11.)$$

and

$$t_2 = t_1 k.$$

The time of a whole period (up and down stroke) T is equal to $t_1 + t_2$, and the number of strokes per second required for hovering is

$$s = \frac{1}{T} = \frac{1}{t_1 + t_2} = \frac{1}{t_1 (1+k)} = \frac{\omega_1}{\pi (1+k)} \quad (12.)$$

From this it appears that s is inversely proportional to the sine of the wing-stroke. For large angles a less number of strokes is required. Neglecting W_2, we have

$$t_1 = n_1 \operatorname{Sin} \phi \sqrt{\frac{2\zeta \gamma \pi \Phi F_1}{g (1+k) G}} \quad . \quad . \quad (11a.)$$

(8.) Determination of the Work.

The resistance is a force W, acting at a distance m from the axis; the work for a stroke is therefore.

$$A_1 = m_1 \int_{a=0}^{a=2\phi} W^1 d\,a \text{ for down stroke}$$

$$A_2 = m_2 \int_{a=0}^{a=\phi} W^{11} d\,a \text{ for back stroke}$$

in which W^1 and W^{11} are resistances; the value of W^1 being given in equation (3.)

The maximum resistance of $W_m{}^1$ is

$$W_m{}^1 = 2\zeta \frac{\gamma}{2g} F_1 n_1{}^2 \omega_1{}^2 \operatorname{Sin}^2 \phi,$$

hence

$$W^1 = W_m{}^1 \frac{\operatorname{Sin}^2 \phi - \operatorname{Sin}^2 (\phi - a)}{\operatorname{Sin}^2 \phi \operatorname{Cos}^2 (\phi - a)}$$

And the work

$$A_1 = \frac{m_1 W_m{}^1}{\operatorname{Sin}^2 \phi} \int_{a=0}^{a=2\phi} \frac{\operatorname{Sin}^2 \phi - \operatorname{Sin}^2 (\phi - a)}{\operatorname{Cos}^2 (\phi - a)} d\,a$$

This integration gives

$$A_1 = \frac{m_1 W_m{}^1}{\operatorname{Sin}^2 \varphi} \left[2 tg \phi \operatorname{Sin}^2 \phi - 2 tg \phi + 2 \phi \right]$$

Reducing,

$$A_1 = \frac{m^1 W_m{}^1}{\operatorname{Sin}^2 \phi} \left[\phi - \frac{1}{2} \operatorname{Sin} 2\phi \right]$$

The work for back-stroke is

$$A^2 = \frac{m^2 W_m{}^{11}}{\operatorname{Sin}^2 \phi} \left[\phi - \frac{1}{2} \operatorname{Sin} 2\phi \right]$$

The total work is

$$A_1 + A_2 = \frac{2 (\phi - \frac{1}{2} \operatorname{Sin} 2\phi)}{\operatorname{Sin}^2 \phi} \left[W_m{}^1 m_1 + W_m{}^{11} m_2 \right]$$

And the work per second

$$(A_1 + A_2) s = s \cdot \frac{2(\phi - \frac{1}{2} \operatorname{Sin} 2\phi)}{\operatorname{Sin}^2 \phi} \left[W_m{}^1 m_1 + W_m{}^{11} m_2 \right]$$

Neglecting $W_m{}^{11}$ compared with $W_m{}^1$ and substituting from (10) the value of $W_m{}^1$, and from (12) and (11a) the value of s; we have the total work per second.

$$A = \frac{2}{\operatorname{Sin}^2 \phi \Phi^{\frac{3}{2}}} G \frac{m_1}{n_1} \sqrt{\frac{\pi q (1+k) G}{2\zeta \gamma F_1}} \quad (13.)$$

Determination of the Value of the Function.

$$\frac{\phi - \frac{1}{2} \operatorname{Sin} 2\phi}{\operatorname{Sin}^3 \phi \Phi^{\frac{3}{2}}} = f$$

For

$$\phi = \frac{\pi}{2}, f = \frac{\pi}{2} = 1.57, \text{ hence } \Phi = 1 \text{ if } \phi \frac{\pi}{2}.$$

For

$$\phi = 0, f = \frac{0}{0}.$$

The quotient for differentials of numerator and denominator is

$$\frac{1 - \operatorname{Cos} 2\phi}{3 \operatorname{Sin}^2 \phi \operatorname{Cos} \phi \Phi^{\frac{3}{2}}} = \frac{0}{0}, \text{ if } \phi = 0.$$

Differentiating again,

$$\frac{2 \operatorname{Sin} 2\phi}{3 (2 \operatorname{Cos}^2 \varphi \operatorname{Sin} \varphi - \operatorname{Sin}^3 \varphi) \Phi^{\frac{3}{2}}}$$

Reducing

$$\frac{4 \operatorname{Sin} \phi \operatorname{Cos} \phi}{3 \operatorname{Sin} \phi (2 \operatorname{Cos}^2 \varphi - \operatorname{Sin}^2 \varphi) \Phi^{\frac{3}{2}}} = \frac{4 \operatorname{Cos} \phi}{(6 \operatorname{Cos}^2 \varphi - 3 \operatorname{Sin}^2 \varphi) \Phi^{\frac{3}{2}}}$$

For

$$\phi = 0, f = \frac{4}{6 \Phi^{\frac{3}{2}}} = \frac{2}{3 \Phi^{\frac{3}{2}}}.$$

For

$$\phi = 0, \Phi = \frac{\pi}{4}$$

hence

$$f = \frac{2}{2 \left(\frac{\pi}{4} \right)^{\frac{3}{2}}} = 0.96.$$

Comparing the values 0.96 and 1.57, we find that the work per second required for a bird to maintain a hovering condition, is generally smaller for small stroke-angles. But equation (11) shows that in this case the number of strokes is very great, and therefore demands a greater expenditure of work in moving the wings outward and inward.

As the following calculation is intended to be approximate, a constant value may be taken for f. The mean of 1.26 and 0.96 is 1.26.

The value $\frac{m}{n}$ varies with the form of the wing.

For rectangular form,

$$m = \frac{3}{4}a;\ n = 0.577\ a \text{ and } \frac{m}{n} = 1.29.$$

For parabolic form,

$$m = \frac{2}{3}l;\ n = 0.479\ l \text{ and } \frac{m}{n} = 1.39.$$

The form of the wing, therefore, has little influence.

Under these special conditions the work, expressed in metre-kilograms, is

$$A = 2.20\,G\sqrt{\frac{G}{F_1}(1+k)} \quad . \quad . \quad (13a.)$$

in which G (the weight of the bird) is in kilograms, F_1 (the surface of the wing) is in square meters.

The number of wing-strokes per second for large angles, by (11a) and (12) is

$$s = \frac{0.78}{l}\sqrt{\frac{G}{F_1(l+k)}} \quad . \quad . \quad (12a.)$$

l being the wing-length in metres. Hence it appears that the greater the wing-surface, the smaller the work required, and the less the number of wing-strokes.

We will consider the three cases in which

$$k = \frac{t_1}{t_2} = \frac{1}{\infty} = 0;\ \frac{t_1}{t_2} = \frac{1}{3};\ \text{and } \frac{t_1}{t_2} = \frac{1}{2}$$

The following table gives for certain birds the weight, length of wing, wing-surface, and the calculated value of s and A.

Name.	Weight in Kilog.	Length of Wing. Metres.	Breadth.	Wing Surface. Square Metre.	Number of Strokes per Second, in Hovering. S.			Work per Second referred to Weight A.			In Kilo-grams. A
	G.	l	b	F	$k=0$	$k=\frac{1}{8}$	$k=\frac{1}{4}$	$k=0$	$k=\frac{1}{8}$	$k=\frac{1}{4}$	$k=0$
Eagle...	3.37	0.92	0.37	0.230	3.2	2.8	2.6	8.43 G	9.77 G	10.4 G	28.4
Crow...	0.52	0.46	0 20	0.061	4.9	4.3	4.0	6.38 G	7 40 G	7.85 G	3.32
Dove....	0.34	0.30	0.13	0 026	9.3	8.1	7.6	7.92 G	9 18 G	9.74 G	2.69
Sparrow	0.03	0.12	0 06	0.0048	15.9	13.7	12.9	5.39 G	6.25 G	6.63 G	0 16

From which it is seen that the work which a bird must do in flight is great in proportion to its weight. A man with the greatest exertion, as in running up stairs, raises his own weight not more than a metre in a second, while the work necessary for flight is at least five times as great. So man will never be able to raise himself on wings by means of his own muscular exertion. The small values which Prechtl obtained are due to the erroneous assumption that the whole work done by a bird is expended in raising its own weight.

From the above tables it appears that an apparatus in which the ratio of wing-surface and total weight is the same as in the case of the eagle, should not weigh more than 8.9 kilograms per horse-power. Considering that still more force is required for progression, that a good non-condensing engine requires 20 kilog. of water and coal per hour, that the proper weight of this machine is five times this value, and that to all this must be added the weight of the wing-apparatus, there seems to be little hope that flying machines can be driven by our present steam motors.

The Admiralty have decided not to incur any expense in making preliminary experiments to test Captain Moncrieff's plan for working ships' guns by means of hydraulic pressure.

ON SKEW BRIDES, AND ON THE CONSTRUCTION OF FALLS BRIDGE OVER THE SCHUYLKILL.*

Falls Bridge, over the River Schuylkill, on the Philadelphia and Reading Railroad, is a stone structure with six arches of eighty-three feet span and twenty-four feet raise. Each arch consists of eight square-built ribs of three by three feet in e section, and each rib sits eighteen inches back of its fellow, making a skew of twelve feet in a width of twenty-four.

Before entering upon a description of this structure and the mode of building it, it is due to the memory of one of the brightest ornaments of our profession (B. H. Latrobe, the elder), that I should refer briefly to the origin and history of ribbed arches, which, from the materials furnished me by B. H. Latrobe, the younger, I may be enabled to do with some little emphasis.

The sketch which I now submit to the Society is a design by Mr. Latrobe, in 1808, for a brick bridge over Rock Run, in Washington, D. C., with an arch of one hundred and fifty feet span and twenty-five feet raise; it will be observed that the arch consists of four ribs of three and six feet in width, connected with transverse arches of eight and ten feet spans, and, from a note upon it, that it is a copy of a bridge previously built by the same engineer over the Medway, in England, and that he had applied for a patent. He also built a brick bridge over the canal in the District of Columbia, about the same time, which is yet standing as he left it more than fifty years ago; it is a ribbed arch of about sixty feet span, and is considerably skewed. I also submit a design of his for a bridge with ribbed brick arches over the River Schuylkill, at Philadelphia, with two spans of two hundred feet, and one of two hundred and fifty feet, which was made in 1802, but which was not executed.

We next find the system renewed in England for carrying wagon roads over the London and Croydon Railway; I quote from Weale's description of one of these structures printed in 1843 :

"This is an oblique bridge built on entirely novel principles, from the design and under the direction of Joseph Gibbs, Esq., Engineer of the Croydon Railway. The whole bridge is of brick work, and instead of the arch being built in spiral courses as in the common skew bridge, it is composed of four ribs or square arches three feet in width, and the direction of the courses, in all these ribs, is at right angles to the roadway over the bridge. It is evident that a bridge may be built on this principle at any angle, however acute, and all the expense and trouble of skew arches avoided. The bridges of this kind on the Croydon Railway are universally admired for their elegance and simplicity." But Mr. Gibbs had been antedated more than a quarter of century by Mr. Latrobe both in England and America; and it is not more remarkable that this simple mode of building oblique arches should have been so long hidden from the architectural world than that extinct races of men, who have left behind them monuments of masonry which are studied to advantage in the present enlightened age, were without the knowledge of the arch in any of its shapes.

The first ribbed arch bridge for sustaining the weight and jar of railway trains in this country, was built on the line of the Philadelphia and Reading Railroad in 1848, at a point known as "Third Crossing." It is a stone structure, with three spans of 42 ft., and a raise of 12 ft. Each arch consists of 4 square built ribs, with a backset of 1¼ ft., and a skew of 5 ft.

Circumstances made it necessary to remove the centres from this structure as soon as the arches were keyed, and for an entire winter they sustained the heavy traffic of that road unaided by backing or spandrels, and thus their sufficient stability was demonstrated in the most practical manner.

This bridge was duplicated by Mr. Edward Miller, on the Pennsylvania Railroad, about a year later, after which the system came into general use.

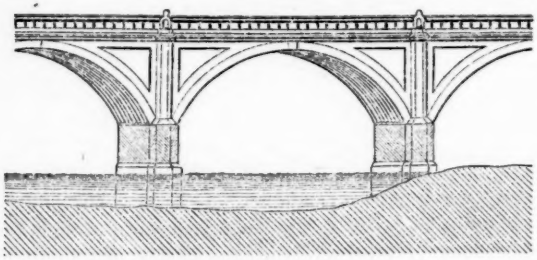
The designs for Falls Bridge were made in 1852, and the work was commenced in 1853, and finished in 1856; it was the most elaborate application of ribbed arches of its date. The feature in its con-

*A Paper read before the American Society of Civil Engineers, by J. DUTTON SEELE, Civil Engineer, Member of the Society.

struction which has attracted most attention is the fact of its occupying exactly the same site as did the wooden structure for which it is the substitute. Steamboats plied under it whilst it was building, and passengers were surprised to see the old wooden structure gradually disappearing and the new stone bridge taking its place, but the most difficult part of the work was the foundations.

The Falls of Schuylkill, which gave name to this locality, was originally a considerable rapids in the river where the waters found their hurried way among granite boulders at the head of tide. These boulders had been connected with deposits of riprap, forming wing dams to drive machinery, and at a later date both the boulders and ripraps had been submerged to a depth of 5 or 6 ft., by the construction of Fairmound dam of the Philadelphia Waterworks, and stern-wheeled steamboats plied over them. Thus it was that the rock bed of the river had become covered with masses of loose stones to a depth of 5 or 6 ft., with about an equal depth of water over them.

As coffer-dams could not be founded upon these loose materials, their sites were cleared with diving bells before they



FALLS BRIDGE.

were sunk, that the filling might rest upon the rock.

The foundations were obtained in from 12 to 15 ft. of water, and in all cases the cut stone masonry not only rested upon, but was fitted to, the rock bed of the river.

The diving bells were made of plate-iron suitably weighted and supplied with air through a hose attached to the top. The workmen remained in them 5 hours at a time, and the air was changed every 15 or 20 minutes.

Two of the piers occupy the same places as did the piers of the old structure, in which cases strong trestles were placed inside of the coffer-dam to sustain the wooden superstructure whilst the old piers were being removed and the new substituted for them.

Two seasons were occupied in obtaining the foundations and raising the piers to the springing line, and one in turning the arches and building the spandrels.

In describing the mode of turning the arches without interrupting the traffic upon the railroad above, or on the river below, it must be observed that the structure which they took the place of was a deck lattice bridge, the bottom chord of which was 5 ft. above the springing line of the stone arches. After the new piers were built, the first operation was to support this lattice superstructure upon strong trestles resting upon the centres and between the skew-backs. These trestles were not removed, and they are the only wood work built into the masonry. It will be observed thus far that we have increased the strength of the old structure by reducing its spans, and the remaining piers of the old bridge were then taken down.

The centres for turning the arches were of lattice, corresponding in plan with the trusses of the old bridge, and the trusses were made use of as a portion of the centring by bolting segments upon them. Working platforms upon which were rail tracks for moving the stone, and derricks for handling them, passed along either side of the bridge, supported upon beams which rested on the chord of the old structure about 10 ft. above the springing line.

These arrangements being completed and the arch stones being ready, the work

of turning the arches was a simple operation and did not consume a great deal of time. That portion of the old lattice trusses above the arches was cut away as the work progressed, and the rail tracks on the top were supported upon the masonry. When the arches were keyed, those portions of the old structure below them were lowered away with the centring.

The tops of the arches were covered with flat stones from 4 to 6 ft. long, which gave some bond to the ribs, enough for ordinary cases; but the constant passage of coal trains caused more vibration than was desirable, and tie rods were placed across the arches, binding the keystones on either side together for the purpose of steadying the ribs while the spandrels were being built.

Four thousand stone, each 3 ft. square, and averaging about 1 ft. thick, were required to turn the arches, and this gave occasion to note an unexpected difficulty in obtaining so large a number of sound stones of one definite size; no bond of masonry is deemed admissible between the ribs of oblique arches.

I also submit to the Society several other plans of stone bridges on the Philadelphia and Reading Railroad, which will indicate the general character of the structures; if they may be deemed of little value, they will do no harm.

The cylindrical spandrel arches have produced satisfactory results, lightening the structure over the piers and giving bond to the spandrels.

All these bridges were built in the place of wooden structures without interrupting the business of the road, and the practice gave an unusual opportunity of observing the extent to which the stability of simple stone arches without the support of spandrels or backing may be depended upon. The centres were generally removed as soon as the arches were keyed, and the backing carried up to those joints of the arches which made angles of 30 deg. with the horizon, and in no case did the arches so supported fail to sustain the heavy trains which were passing over them, without material vibration.

The plan of "Peacock's Locks Bridge" was a ribbed arch of 76 ft. span and 23 ft. raise over a canal. It was necessary to turn this arch in a severe winter, with the temperature considerably below freezing point, from the time the first stone was laid until the centres were removed, and it was interesting to observe the settling of the ribs as the frost left the mortar. They separated at one point as much as 3 in., but retained their stability perfectly, and after the cracks were filled and the spandrels built, no further derangement took place, and it would take a close observer, at this day, to discover any of the injurious results of that hard, and, as many thought, precarious winter work.

At the usual monthly meeting of the Association of Engineers, in Glasgow, Mr. Charles H. Reynolds, read a most elaborate and carefully prepared paper on "The Arrangement of the Fastenings of Iron Structures," confining himself more particularly to the functions of iron plates and rivets, individually and collectively, in malleable iron structures, subject to local straining and varying conditions of equilibrium — taking for example an iron-built ship, as being about the best instance of one structure being subject to severe alternations of repose and distress, and irregularly recurring periods of compression, tension, and shearing. He entered particularly into the plating of ships and the various modes of riveting, and quoted the results of the latest experiments on such. The paper was listened to with much interest, and a full discussion ensued.

Into one of the quietest coves of the Land's End district, immediately under the shadow of the ancient Logan Rock, is brought the cable of the Falmouth, Gibraltar, and Malta Electric Telegraph. There, in the valley of Porthcurno, is a large establishment, in which about a dozen clerks were, before the cable was broken in the winter, actively engaged in communicating with the East. The mischief is now repaired, and since the restoration of the Porthcurno cable, messages have been regularly received from India, Singapore, and Java, within three or four hours of absolute time.

The floating capital upon the Mississippi river is estimated at $1,500,000,000.

THE NATURE OF THE EARTH'S INTERIOR.

By DAVID FORBES.

From "Nature."

In a previous discourse on volcanoes, I directed attention to the phenomena of volcanic action, specially considered in relation to the part which such igneous or internal forces have played in determining the grand features of the external configuration of the sphere upon which we live.

If now we follow up this subject still further, it will naturally lead to an inquiry into the nature of the internal substance of the globe itself, within which the foci of such agencies must be situated; quite independent of this, however, I have little doubt but that many of you must at some time or other have already asked yourselves the question—What does the central mass of the earth beneath us consist of?

The answer which, in the first instance, would, I imagine, be most likely to suggest itself to your minds, would be that it consisted of solid stone, such as you see forming the body of its mountains, the foundations of its continents, and the rock basins which contain its seas. The belief in such an hypothesis would, however, be rudely shaken by the first personal experience of the shock of an earthquake, the sight of a volcano in eruption, or the consideration of the immense faults which have dislocated many parts of the solid land; since, so far from disposing us to regard the ground under us as entitled to the appellation of the terra firma, so commonly used by the ancients, the study of such phenomena could not but suggest grave doubts in our minds as to whether the earth was, after all, anything like so solid or stable as we at first sight felt inclined to imagine.

But very little inquiry into the subject is necessary, however, to convince any one of the great difficulties in the way of obtaining a satisfactory answer to this question, and to prove that at present we do not have at our command sufficient data or evidence to enable us to arrive at a thoroughly conclusive solution of this most interesting problem.

As the rapid advances made by the natural sciences are, however, daily adding to our information on this subject, and thus enabling us to correct or modify our previous deductions, so as to form a more and more trustworthy opinion on the nature of those parts of our globe, which, from their position, must always remain inaccessible to our powers of direct observation, I have imagined that a short sketch of the present state of our knowledge concerning the probable constitution of the interior of the earth might prove interesting.

In treating this subject, we will first consider what has already been done in the way of direct examination of the earth's substance in depth; yet when it is remembered that the mean diameter of our planet is some 7,912 miles, whilst the greatest depth hitherto attained by man's direct exploration has not even yet reached one mile from the surface downwards, this disproportion appears so enormous as to render it self-evident, in the pursuit of this inquiry, especially as regards the more central portions of the earth, that we must in the main rely upon data furnished by calling in the aid of the natural sciences. The direct examination of the exterior of the earth, even when restricted to this depth, does nevertheless furnish us with many important data from which to start in this to a great degree speculative inquiry, and to some of these we shall now direct attention.

It must first of all be remembered that all the rocks which we meet with at the surface, and which compose so much of the solid exterior of our globe as is actually known to us, may be arranged under two principal heads, viz., the volcanic or endogenous rocks, *i.e.* those formed within the body of the earth itself, and the sedimentary or exogenous, *i.e.* those rocks formed, or rather reconstructed, upon its surface, out of the débris of previously existing rocks arranged in beds or strata by the mechanical action of water.

It was long taken for granted by geologists that the lowest sedimentary strata, in their normal or in a more or less altered condition, rested directly upon granite, which was for a long time regarded as the foundation upon which they, in the

first instance, had been deposited, since this rock has been looked upon as the oldest of all, and as representing the primeval or original surface covering of the earth.

Later researches, however, have proved this hypothesis to be untenable, since it appears that no instance of a granite has as yet been met with in nature, which, if followed up, does not at some place or other break through, and alter or disturb, more or less, the stratified rocks in immediate contact with it; so that it naturally follows that such stratified rocks must have preëxisted on the spot, or in other words, that they were older in geological chronology than the granite which came to disturb them.

In the present state of geology, however, it is utterly impossible for us to point out any variety of rock whatsoever as the one which may have served as a foundation upon which the oldest sedimentary rocks were originally deposited, in fact the oldest rocks which we know of at present are themselves sedimentary rocks (mostly in an altered condition) belonging to the Laurentian series in Canada, and as yet it has not been found out what these sedimentary beds may in their turn rest upon, *i.e.*, what is actually below them.

As, therefore, we have not as yet been able to reach down to investigate directly any rocks lower in the geological series than those pertaining to the Laurentian formation, we will now turn to the volcanoes, in order to examine the mineral products which they bring up for our consideration, from depths vastly beyond those which we can ever hope to reach directly. What volcanoes teach us with regard to the nature of the earth's interior, at a depth from which they derive their supply of mineral matter, may be summarized as follows:

That at this depth, the earth's substance exists in a state of perfect molten liquidity, forming as it were a sea of molten rock, analogous in character to the eruptive rocks which have broken through the earth's crust in former times. Secondly, that the mineral products ejected from volcanoes are very similar to one another in chemical and mineral constitution, no matter what part of the globe they may emanate from. And, lastly, that from the same volcanic orifice, and during the same eruption, lavas of two totally different classes may be emitted, viz., the light acid, or trachytic lava, analogous to the granites, felsites, etc., of the oldest period, and the heavy basic or pyroxenic lava, all but identical with the dark basaltic or trappean rocks, commonly met with as dykes, &c., disturbing most of the different sedimentary formations.

Another deduction from the study of volcanic phenomena, indicating that at a certain depth below their surface they must be in connection with a continuous sea of molten lava, is based upon the influence which the moon appears to have on volcanic eruptions; this opinion seems to have been confirmed by observations of Prof. Palmieri made during the last eruption of Vesuvius, on which occasion he reported that distinct tidal phenomena could be recognized, thereby indicating that the moon's attraction occasioned tides in the central zone of molten lava, in quite a similar manner as it causes them in the ocean. A further corroboration of this view is seen in the results of an examination of the records of some 7,000 earthquake shocks, which occurred during the first half of this century, compiled by Perry, and which, according to him, demonstrate that earthquakes are much more frequent in the conjunction and opposition of the moon than at other times, more so when the moon is near the earth than when it is distant, and also more frequent in the hour of its passage through the meridian.

Returning now to the more direct examination of the superficial parts of the earth, we find that the results of mining operations have also thrown considerable light, not only on the mineral nature of the rocks encountered in depth, but also upon some of their physical conditions. A numerous set of experiments made in deep mines in various parts of the world, often far distant from one another, has most conclusively proved that the temperature of the earth, at least as deep down from the surface as has been explored by man, increases in direct ratio as we descend towards its centre. Other observations on the temperature of the water from deep-seated and hot springs, and from artesian wells, fully confirm the experiments made in mines, and show that the temperature of the water furnished by them also becomes higher in proportion

to the depth of the source from which it is derived.

As might naturally be expected, the interference of local causes renders it a matter of considerable difficulty to determine the true mean general rate of such increase in temperature of the earth's substance downwards; still, in the main, observers all agree in placing it at somewhere between 1½ deg. and 2½ deg. F. for every 100 ft. in depth, so that we cannot be far wrong, if for our purpose we estimate it at 2 deg. F. for every 100 ft. in depth, or a rate which amounts to 121 deg. for each geographical mile nearer the earth's centre. Since no facts are at the present time known which can in any way invalidate the supposition that this or a somewhat similar rate of increase in temperature holds good in still greater depths, it is perfectly correct and justifiable reasoning to assume that such is actually the case, and therefore a simple calculation will show that at a depth of about 25 geographical miles from the surface downwards, a temperature of about 3,000 deg. F. should be attained, which would represent a heat at which iron melts, or one sufficient to keep lava in a state of perfect molten liquidity at the surface of the earth. As it must be remembered, however, that at this depth the substance of the earth would be exposed to the pressure of the superincumbent mass, and as it has been shown by experiment that many substances become more refractory—*i. e.*, require a greater degree of heat to melt them—when exposed to pressure than when at the surface, the above calculation will have to be modified considerably in order to meet this condition. Unfortunately, we have not as yet sufficient data at command to enable us to estimate the true ratio in which the melting points of such rocks would become elevated by pressure; yet we may safely take it for granted, after allowing far more than the maximum rate of increase, deduced from the experiments of Bunsen and Hopkins, that we should not require to sink so deep again in order to attain a temperature fully sufficient to keep such substances in a state of fusion, or, in other words, this deduction necessitates the supposition that the solid rock crust of the earth cannot, at the utmost, be more than 50 miles in thickness.

If we now reason from the above data as premises, it will follow as a natural consequence that our globe must in reality be a sphere of molten matter, surrounded by an external shell or crust of solid matter, of very insignificant thickness when compared to the diameter of the entire globe itself; or, in other words, this deduction represents exactly such a state of things as would ensue in the event of a sphere of molten matter becoming consolidated on its exterior by the cooling action of the external atmosphere; and the figure of the earth itself, which is an ellipsoid of revolution, *i. e.*, a sphere somewhat flattened in at the poles, but bulging out at the equator, being that which a plastic mass revolving round its own axis would assume, is regarded by natural philosophers in general as all but conclusive evidence that the earth at an early period of its history must have been in a fluid condition.

Although the doctrine that the earth is a molten sphere, surrounded by a thin crust of solid matter, was all but universally taught by geologists, there have of late years been brought forward several arguments to the contrary, which apparently are more in favor of its being a solid or nearly solid mass throughout, and these arguments are fully entitled to our consideration, as our object is not to defend any particular theory, but to arrive as nearly as we can at the truth. I will, therefore, in the first place, proceed to scrutinize all which has been brought forward in opposition to the older hypothesis, and then to consider whether any other explanation yet advanced is more in accordance with the facts of the case.

First of all we have to answer the question as to whether it is possible for such a thin crust to remain solid, and not at once to become melted up and absorbed into the much greater mass of molten matter beneath it? This would doubtless be the case, if the central fluid mass had any means of keeping up its high temperature, independently of the amount of heat it actually possessed when it originally assumed the form of an igneous globe. This question, however, in reality answers itself in the negative, since it is evident that no crust could even commence to form on the surface, unless the sphere itself was at the moment actually giving off more heat from its outer surface to the surrounding atmosphere than it could supply from its

more central parts, in order to keep the whole in a perfectly fluid condition, so that when once such a crust, however thin, had formed upon the surface, it is self-evident that it could not again become melted up or re-absorbed into the fluid mass below.

The external process of solidification due to refrigeration would then continue going on from the outside inwards, until a thickness of crust had been attained sufficient to arrest or neutralize (owing to its bad conductibility of heat) both the cooling action of the surrounding air and the loss of more heat from the molten mass within; and thus a stage would soon be arrived at when both these actions would so counterbalance one another that the further cooling down of the earth could be all but arrested—a condition ruling at the present time, since the earth-surface at this moment, so far from receiving any or more than a minute amount of heat from the interior, appears to depend entirely, as regards its temperature, upon the heat which it receives from the sun's rays.

We have next to consider the argument that, if the earth's exterior was in reality only such a thin covering or crust, like the shell of an egg, to which it has often been likened, such a thickness would be altogether insufficient to give to it that stability which we know it to possess, and that consequently it could never sustain the enormous weight of its mountain ranges, such as, for example, the Himalayas of Asia or the Andes of America, which are, as it were, masses of rock piled up high above its mean surface-level.

At first sight, this style of reasoning not only appears plausible, but even seems to threaten to upset the entire hypothesis altogether. It requires but little sober consideration, however, to prove that it is more, so to speak, sensational in character than actually founded on the facts of the case; for it is only requisite for us to be able to form in our minds some tangible idea of the relative proportion which the size of even the highest mountain bears to that of the entire globe itself, to convince us, if such a crust could once form and support itself, that it could with ease support the weight of the mountains also. The great Himalaya chain of mountains rises to a maximum altitude of 31,860 ft., or six miles above the level of the sea; and if the earth could be seen reduced in scale down to the size of an orange, to all intents and purposes it would look like an almost smooth ball, since even the highest mountains and the deepest valleys upon its surface would present to the eye no greater inequalities in outline than the little pimples and hollows on the outside of the skin of an ordinary orange. If this thin crust of the earth can support itself, it is not at all likely to be crushed in by the comparatively speaking insignificant weight of our greatest mountain chains, for in point of fact it would be quite as unreasonable to maintain such a position, as to declare that the shell of a hen's egg would be crushed in by simply laying a piece of a similar egg-shell upon its outside.

That a very thin spheroidal crust or shell enclosing a body of liquid matter, such as an ordinary fowl's egg, does possess in itself an enormous degree of stability and power to resist pressure from without, is easily demonstrated by merely loading a small portion of its surface with weights as long as it does not give way under them. Even when placed on its side (or least strong position) it was found that a portion of the shell only one quarter of an inch square would sustain several pounds weight without showing any symptoms of either cracking or crushing; or, in other words, this simple experiment indicates that if the external crust of the earth was but as thick and strong in proportion as an egg-shell, it would be fully capable of sustaining masses equal in volume and weight to many Himalayas piled up one atop of another, without any danger whatever to its stability.

The next argument which has been advanced against the probability of the major part of the earth's substance being in a fluid condition, is one based altogether upon astronomical considerations. It having been demonstrated when two clocks are set agoing, the pendulums of which are similar to one another in all respects, except that whilst the bob of the one is solid, that of the other is hollow and filled with mercury, that the latter will swing somewhat faster, and consequently the clock gain time upon the former. The late Mr. Hopkins, of Cambridge, applied this observation to the consideration of movements of the earth in space, and by a very elaborate course of mathe-

matical reasoning and calculation, demonstrated that the earth, if not quite solid, must be nearly so, since according to his results, if it was merely a comparatively thin shell filled with liquid matter, the ratio of certain of its movements (the precession or nutation) would differ considerably from what they are actually known to be, and these conclusions appeared to be confirmed by the subsequent calculations of Sir William Thomson and Archdeacon Pratt. Although grave doubts suggested themselves as to the correctness of the values used in these calculations for two of their most important elements, viz., the condensing action of pressure, and the expanding action of the very high temperatures within the globe —both of which have not as yet been determined with any certainty—and although it might also be surmised that the conditions of a pendulum-bob of polished glass filled with heavy slippery mercury swinging at the end of a rod, must be extremely different from those of a nearly spherical globe filled with viscid, sticky lava revolving around its own axis, still geologists felt themselves quite unable to answer the arguments of the astronomers and mathematicians; and since none of them appeared to be sufficiently versed in either astronomy or mathematics to be able to submit the method of reasoning or the calculations to any strict scrutiny, they felt themselves, reluctantly no doubt, compelled to bow to the decision of such eminent authorities.

So stood the matter until the summer of 1868, when, fortunately for the advancement of this inquiry, M. Delaunay, now Director of the Observatory at Paris, an authority equally eminent as a mathematician and an astronomer, was induced to undertake the reconsideration of this problem—a labor which has not only resulted in altogether reversing the above decision, and demonstrating the complete fallacy of the premises upon which so much elaborate reasoning had been expended, but which proved conclusively by experiment that a sphere filled with liquid matter would, under circumstances such as are present in the case of the earth, behave in precisely the same manner as an entirely solid one, and, consequently, that the fact of the earth being either solid or liquid in its interior, could neither have any influence whatever on the rate of precession or nutation, nor be of any use as a means of deciding as to the real or approximative thickness of the earth's crust.

It may also be added that the conclusions arrived at by Mr. Hopkins, even when supported by Sir William Thomson and Archdeacon Pratt, were not universally acquiesced in; the celebrated German physicist, Helmholtz, amongst others, was not satisfied as to their correctness, and in opposition to the deductions of Sir William Thomson, that the earth's crust must be some 1,000 miles in thickness, we have the entirely opposite conclusions of Mr. Henessey, whose calculations tend to show that the earth's crust cannot be less than 18 miles or more than 600 miles in thickness. We may now, however, fairly conclude that all the objections as yet advanced from an astronomical point of view against the theory of the fluid condition of the interior of our planet, have been invalidated or explained away.

The only other argument in favor of internal solidity is one which bases itself upon the law, announced upon theoretical considerations by Professor Thomson in 1849, that the fusing points of bodies must become more elevated when subjected to pressure, or, in other words, that under the influence of pressure, bodies will require more heat to melt them.

Starting from this, Bunsen argued that the earth could not be other than solid to the core, since the enormous pressure accumulated at the centre would cause its internal substance to become so infusible that it could not remain in a molten state. To a certain extent this law was corroborated by the experimental researches of Bunsen and Hopkins, made upon some of the easily fusible substances, like wax, spermaceti, paraffine, and sulphur; but as far as the later experiments went, it was not confirmed either in the case of metallic substances, nor did it appear to hold true with other than the more easily compressible bodies.

In the case of the earth, therefore, the conclusions of Bunsen cannot be accepted, since we have to deal with materials to which, as yet, this law has not been proved to apply; still, assuming, as seems most probable, that the materials composing the earth's mass do become to some extent more and more infusible according as they approach nearer to its centre, it

must, on the other hand, be remembered that this would be more or less neutralized by the expansion which these substances would undergo from the action of the internal heat; and as incontrovertible evidence has been produced to prove that the temperature of the earth downwards from the surface increases in direct ratio with the depth, it seems most probable that the combined effects of expansion and elevated temperatures would more than counteract any tendency to solidification due to the effects of pressure.

Having now taken into consideration the various objections which have been urged against the theory of the earth's internal fluidity, as well as devoted some consideration to the opposing view of its solidity, it will be noticed, if we pass in review some of the distinctive features of the two hypotheses, that the former theory is a legitimate deduction from the data afforded by the direct study of the earth itself, whereas the latter, on the contrary, instead of making the explanation of the earth's phenomena its starting point, devotes itself almost exclusively to the task of proving that it could not be fluid.

Thus, how is it possible, if the earth's mass be solid throughout, to account for the great upheavals or sinkings down of large portions of the rock formations which compose its external crust? Do not these phenomena lead to the direct inference that the external crust cannot, by any possibility, rest in depth upon an unyielding mass of matter in the solid state, but that it must necessarily be superposed upon some more or less fluid substance, which by its mobility can, when some one portion of the crust above sinks down, become displaced, and so make room for it by elevating, or, as it were, floating up some other part of the same?

In like manner the hypothesis that the earth is essentially solid necessitated that the phenomena of volcanoes should be explained upon the supposition that they had their sources in numerous small isolated local basins of molten rock scattered over the surface of the globe; a view which is altogether inconsistent with the results of chemical and mineralogical investigation, which proves that the ejected products are identical in constitution even if taken from volcanic vents the most distant from one another, nor does such a theory attempt to explain the tidal phenomena of volcanic outbursts and earthquakes previously alluded to.

So far, therefore, as we have gone into this subject, we may regard the balance of evidence as proving that at a depth of about 50 miles or less from the surface, there exists a continuous zone of molten rock or lava, such as is brought up to the surface by volcanic eruptions. Let us now consider how deep this zone or stratum of molten matter is likely to extend, and also what forms the more central mass of the earth below it.

In order to answer these questions we must look to other than direct evidence, and first of all must inquire whether the consideration of the mean density, or, in other words, the actual weight, of the earth itself, can throw any light upon these abstruse points. The consideration of the attraction which bodies exert upon one another in the ratio of their magnitude, has enabled the physicist to effect the at first sight apparently impracticable task of determining the entire weight of the earth itself; but it is out of our province to describe the mode of doing so, and we must content ourselves by accepting as a fact the results of such investigations, which prove that the total weight of our planet is as near as possible $5\frac{1}{2}$ times the weight of a similar globe of pure water. Knowing now that the mean density, or specific gravity, as it is also called, of the earth is $5\frac{1}{2}$, and also, from direct experiment, that the mean density of the entire solid rock forming its external crust cannot be higher than $2\frac{1}{2}$, or less than half that of the entire sphere, it naturally follows that the central parts must be very much more heavy in order to account for so high a mean figure as $5\frac{1}{2}$, and it has been calculated that if we suppose that the earth was composed of three concentric portions of equal thickness, each in turn increasing in density towards the centre in arithmetical progression, we should then have an outer circle of specific gravity $2\frac{1}{2}$, or as heavy as rock, an intermediate zone of 12, or as heavy as quicksilver, and a central nucleus of about 20 times the density of water, or as heavy as gold.

This increase of density has sometimes been erroneously represented as entirely due to the effects of the enormous pressure of the superincumbent mass; but this supposition is quite untenable, since

the tendency of all the numerous experiments made in this direction has been to prove that no substances can be compressed or condensed to an indefinite extent, since what may be termed their approximative maximum density is soon attained, beyond which the effects of pressure become so much smaller and smaller in proportion to the force applied, that at last the further condensation effected by still greater pressure is all but inappreciable. Besides this, it must not be forgot that the crust of the earth is a species of dome like the shell of an egg, which supports itself without resting or floating upon its fluid centre; and further that the earth's high internal heat, by causing the materials which compose it to expand, must also counteract the effects of superincumbent pressure, so that when all these facts are taken into due consideration, it appears quite evident that the materials which actually form the mass of the interior must be infinitely denser than any of the rocks met with on the surface, and that they must be metallic in their nature, since no other bodies are known which could at all fulfil these conditions of density.

If now we suppose that the earth's interior is composed of a series of concentric zones or layers made up of substances which are of more and more dense nature as they are situated nearer the centre, and that the external one is rock of a density of 2.5, a calculation will show that the centre or nucleus will be about 10, or as heavy as silver. If now we suppose that the zone of molten lava, which we have already concluded must exist at a depth of about 50 miles below the surface, has a density of 3, or say even 4, to give the fullest allowance for the condensing effects of superincumbent pressure, then we should find by calculation that this zone could not extend deeper than about 400 miles, since below this depth the matter would be so heavy that its density can only be explained on the supposition that it is made up of metallic compounds, and as the density of the still lower zones will continue to increase up to the very centre of the earth, the inference is that the whole of this great central mass situated at a distance of some 450 miles or less below the surface, is actually formed of metals and their compounds.

Whether this great central metallic nucleus is fluid or solid may next be inquired into. According to Bunsen's theory, previously alluded to, it ought to be solid, for owing to the enormous pressure to which it would be exposed, the solidification of the molten sphere should first commence at the centre. This view would be quite correct if the earth was composed of highly compressible non-metallic materials; but since this is not the case, and since, as before alluded to, the experimental data already obtained indicate that neither the metallic nor the less compressible substances become more refractory in proportion to the increase of pressure, we are more justified in assuming that the central nucleus also must be in a fluid condition, and the more so, not only because we know that metallic compounds are, as a rule, infinitely more fusible than rock silicates, but also as the well-known high temperature of the earth's interior would, by its expanding action, tend to counteract the effects of the pressure.

In summing up this inquiry, the balance of evidence appears to me to be decidedly in favor of the hypothesis that the interior of our earth is a mass of molten matter arranged in concentric layers or zones according to their respective densities, and the wole enclosed within a comparatively thin external crust or shell.

The manufacture of reaping and mowing machines has attained such large proportions as to make it one of general interest. The annual production is now estimated at about 125,000 machines. Few facts more clearly demonstrate the immense wealth of the farmers of America than that they expend each year about $20,000,000 in the purchase of implements of this one class.

Mr. F. R. Delano, Superintendent of the St. Paul & Pacific Railroad, contributes an article to the "St. Paul Press," on narrow gauge railroads, in the course of which he recommends that all the main lines across the American Continent should consist of four tracks of the 4 ft. 8½ in. gauge, two tracks for passengers and two for freight, with sidings at every 10 miles to admit of trains passing each other.

IMPROVEMENTS IN THE MANUFACTURE AND MELTING OF IRON AND STEEL.

From "The Mining Journal."

Messrs. Edwin Sunderland, manufacturer, and John F. Parker, chemist, of Birmingham, in describing their new patent, say:

Our improvements in the manufacture and melting of iron and steel, consist in the processes or modes of treatment hereinafter described.

In carrying our invention into effect, we take petroleum or other like volatile oil, and place it in an air-tight cistern, surrounded with a covering or jacket, and into the said jacket we introduce boiling water or by preference steam, or by means of a coil of piping within the cistern and under the surface of the oil, through which piping steam is passed, we raise the oil to the required temperature. We prefer a temperature of about 212 deg. Fahr. The top of the covering or jacket is provided with a self-acting valve, regulated to the desired pressure. Through an inlet-pipe we pass a current of air over the surface of the petroleum or volatile oil, which air becomes thereby carburized or charged with the vapor of the oil. By an outlet-pipe, we conduct the carburized air into a larger pipe entering the tuyere of the blast furnace or cupola employed in the manufacture or melting of the iron or steel, which larger pipe constitutes a common conduit, into which all the gases and vapors supplied to the furnace or cupola at the tuyere are passed, and by which they are conducted to the furnace or cupola. The inlet and outlet pipes are each provided with a tap.

In a retort or close chamber, exposed to heat, we place the compound called chloride of lime or bleaching powder, intimately mixed with about one-eighth its weight of dry crushed charcoal, coke, or other carbonaceous matter. This mixture evolves chlorine and carbonic oxide; or we use chloride of lime or bleaching powder alone, which, on being heated, evolves hypochlorous acid gas or a mixture of chlorine and oxygen. When we use chloride of lime or bleaching powder without carbonaceous matter, we prefer to use quicklime intimately mixed therewith in the proportion of one part by weight of quicklime to three parts by weight of chloride of lime. This admixture of quicklime with the chloride of lime facilitates the discharging of the retort and the separation of the gaseous portion of the chloride of lime from the lime. Through an inlet pipe we pass a continuous current of air over the materials in this retort or chamber, and by an outlet pipe the gaseous mixture is conducted into the larger pipe, hereinbefore referred to, which receives the carburized blast and conducts it into the tuyere of the blast furnace or cupola. The inlet and outlet pipes are provided with taps respectively.

In another retort or close chamber, exposed to heat, we place equal parts by weight of quicklime and nitrate of soda, which mixture evolves uncombined oxygen and nitrogen, nitrous acid, and nitrous oxide gases. Through an inlet pipe we pass a current of air over the materials in this retort or chamber, the gas or gases evolved being conducted by an outlet pipe into the larger pipe receiving the carburized blast, and the blast and gas or gases from the first retort or chamber, hereinbefore referred to, and which larger pump is the common conduit of the aforesaid gases and air. The inlet and outlet pipes are provided with taps respectively. The residuum or non-gaseous portion from these last-named materials being treated with boiling water, yields a solution of caustic soda mixed with lime. By subsidence these may be separated and utilized in any convenient manner.

Or, instead of driving currents of air over or through the different cisterns, retorts, or chambers, charged as described, air may be admitted through openings in them. Outlet pipes leading into the larger pipe, acting as the common conduit, conduct the air charged with the gas or vapor into the said conduit by the natural draught only of the furnace or cupola, without pressure of air by artificial means.

For the purpose of storing and equalizing the flow of the gases from the chambers or retorts described, a reservoir or holder may be interposed between each

chamber or retort, and the common conduit by which the gases and vapors are conducted to the cupola or furnace. Taps or stop-cocks, situated between the retorts and their respective reservoirs or holders, and other taps or stop-cocks between the said reservoirs or holders and the conduit, give complete control over the relative quantities of the gases or vapors admitted to the furnace or cupola.

We do not think it necessary to describe or represent the retorts and reservoirs or holders referred to, as no special construction of the same is required, retorts and holders such as are used for like purposes being suited for use in carrying our invention into effect.

The air charged with the vapor of petroleum or other like volatile oil, besides acting as gaseous fuel, also acts powerfully as a reducing agent, and rapidly effects the reduction of the iron from the ore. The air charged with chlorine or chlorine and carbonic oxide removes wholly or mainly any sulphur or phosphorus with which the ore or reduced iron may be contaminated, and the air charged with oxygen, nitrogen, and nitrous acid and nitric oxide, promotes combustion, and rapidly raises the materials to the temperature required. The air charged with vapor of petroleum may be used throughout the smelting and melting processes, and the air charged with chlorine or chlorine and carbonic oxide, as well as the air charged with oxygen, nitrogen, and nitric oxide, are employed only during part of the smelting and melting processes.

Having now described the nature of our invention and the manner in which the same is to be performed, we wish it to be understood that we do not limit ourselves to the precise details herein described, as the same may be varied without departing from the nature of our invention; but we claim as our invention the improvements in the manufacture and melting of iron and steel hereinbefore described—that is to say, the use of air charged with the vapor of petroleum or other like volatile oil in blast furnaces and cupolas, for the manufacture and melting of iron and steel; also the use in the blast furnace or cupola of air charged with hypochlorous acid, chlorine, or chlorine and carbonic oxide, for removing sulphur and phosphorus, and the use of air charged with oxygen for rapidly raising the heat of the blast furnace or cupola to the required point for the smelting and melting of the iron and steel, the said gases and vapors being used substantially in the manner hereinbefore described.

THE RESISTANCE OF FLUIDS.

(Continued from page 431.)

RESISTANCE OF THE ATMOSPHERE.

The majority of authors who have treated of the resistance of gas, have admitted that it should be the same as that of a liquid of the same density; hence they have used formulas equivalent to

$$R = W A \frac{V^2}{2g}$$

in which it is assumed that the resistance is proportional to the square of the velocity. The first precise experiments upon the resistance of air are those of Robbins. He caused plates of different forms and dimensions to rotate about a vertical axis, their plane passing through the axis. These experiments were repeated with the same apparatus by Hutton, in 1786 and 1788. Observations of the same kind were afterwards made by Borda, by means of a similar apparatus, the axis, however, being horizontal. Finally, M. Thebault made investigations at Brest in 1826, with Borda's apparatus. The results correspond with those obtained for the resistance of water. For the same body the resistance increases sensibly as the square of the velocity; but more rapidly than the area of the plate, especially when it is near the axis. This is due to the inequality of velocities of points at different distances from the axis. In 1835, at Metz, Piobert, Morin, and Didion, made experiments in which a plane was affected with a uniform motion perpendicular to its direction. These authorities have represented the resistance by the formula

$$R = W A \left(0.03 + 1.357 \frac{V^2}{2g}\right)$$

in which there is a term independent of the velocity. For velocities from 4 to 9

metres, one may neglect this term without sensible error and unite

$$R = 1.357\, W A \frac{V^2}{2g}$$

Poncelet deduces from all these experiments $k = 1.3$

These authors have experimented upon bodies of different forms; on triedral solids, on cones, hemispheres, and spheres. Unfortunately they have neglected to compare the coefficients obtained with those which thin plates of the same surface as their principal section perpendicular to the motion would give. For spheres, old experiments of Newton and Hutton show that for velocities greater than 8 to 9 metres the value of the coefficient is about 0.54.

The results above mentioned are not applicable to great velocities of artillery projectiles. Bodies moving in the air are attended by liquid bows and sterns (as in the case of motion in fluids) whose volume may be three times that of the projectile. This phenomenon is perceptible in the projection of bombs; which are often seen followed by a dark fluid mass of paraboloidal form; the length being over three times the diameter of the projectile; at the same time the density of the air in front increases rapidly with the velocity. These various causes make the resistance increase more rapidly than the square of the velocity. As the motion of projectiles varies, it is useful to show how one may determine by experiment the law of resistance. It is well known that the velocity of a projectile at any point of its path may be obtained by means of the ballistic pendulum. Experiments are made at two distances, a and a', upon two equal projectiles, shot horizontally with the same charge of powder. The results are the same as if trial had been made upon a single projectile. If a and a' differ little, it may be assumed that the resistance R has not sensibly changed during the interval, and therefore, that the work of this force may be expressed by

$$R\,(a-a').$$

At the same time the loss of living force is

$$\tfrac{1}{2}\frac{P}{g}\cdot(V^2-V'^2);$$

P being the weight of the projectile and V and V′ the measured velocities. We have then

$$R\,(a-a') = \frac{P}{2g}(V^2-V'^2)$$

$$\therefore R = \frac{P\,(V-V')\,u}{g\,(a-a')};$$

u being the mean velocity, $\frac{1}{2}\,(V+V')$.

But if k is the coefficient of resistance for the velocity u, and r the radius of the bullet, we have

$$R = k\,W\,.\,\pi r^2\,\frac{u^2}{2g}$$

$$\therefore k = \frac{2\,g\,R}{\pi\, r^2\, u^2},$$

or putting for R its value,

$$R = \frac{2\,P\,(V-V')}{W\,\pi\,r^2\,(a-a')\,u}$$

a formula which gives k and therefore R.

M. Probert has been led by experiments made at Woolwich by Hutton, and at Metz by himself, to represent the resistance by a formula of the form

$$R = k\,W A \frac{V^2}{2g}(1 + a\,V)$$

which, according to Didion, may be written

$$R = \pi r^2\, u^2\, 0.027\,(1+0.0023\,u).$$

For oblong projectiles with ogee front, of cylindrical body, plane behind, instead of the coefficient 0.027, should be written 0.018, and if the posterior portion is concave, 0,020 should be substituted.

The last formula may be written

$$R = 0.4077\, W A \frac{V^2}{2g}(1 + 0.0023\,V);$$

V being the mean velocity.

A few words about the resistance of surfaces of parachute or sail form. According to M. Didion, if a curved surface with a head of one-third or one-fourth its length moves in air, convexity in front, with a velocity of from 0 to 8 metres, then the resistance is only 0.77 of what would be experienced by a plane surface of area equal to the projection of the curve surface perpendicular to the direction of motion. But if the concavity is in front, the resistance is 1.94, that of the plane being 1. M. Thibault, in his experiments made on sails with a belly equal to a seventh of their yard, has arrived at the remarkable result that for inclinations greater than 45° the re-

sistance is the same as if the sail were developed into a plane; but it is much greater than for the developed sail, if the inclination is slight. This result seems to show that the elasticity of air plays a more important part than is generally supposed, and that under such inclinations we cannot treat air as a liquid of the same density. Poterat, in the introduction to his "Theorie du Navire," expresses the opinion that, whatever may be the incidence of the wind upon the sail, its action is nearly normal at every point; and he gives many striking examples of the discrepancies between the results of practice and the theory generally adopted. In order to avoid intricate calculations the sails of ships are generally regarded as plane. The real action of wind upon sails, unfortunately as yet little understood, invites the special attention of experimenters and geometers.

A NOTE ON METEOROLOGY.

By PROF. ORAN W. MORRIS.

The law of storms as developed and laid down by W. C. Redfield, Esq., has been tested and is now recognized by our Governmen, in the Signal Service, under the efficient Superintendent, Gen. Meyers.

The law of progression in the temperature may be said to be similar, though not developed as yet; but we think, that upon examination, such will prove to be the case, and as an illustration of the regular onward general movement we will take the month of January, 1871. The maximum temperature of that month in California was on the 3rd; in Montana and Colorado on the 9th; in Illinois, Minnesota, Nebraska and Utah on the 10th; in Missouri and Kansas on the 11th; in Mississippi, Arkansas, Tennessee, Indiana, Wisconsin and Iowa on the 12th; in Vermont, New York, Pennsylvania, North Carolina, Kentucky, Ohio and Michigan on the 13th; in Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, Virginia and South Carolina on the 14th; in New Jersey, Delaware, Maryland, and District of Columbia on the 15th; in Louisiana on the 24th; in Texas on the 25th; in Georgia on the 30th, and in Florida on the 31st.

Its general course was eastward, while it stretched latterly both north and south, though not down to the Gulf of Mexico till later. There are some irregularities in the movement, but probably owing to local and physical causes.

The movement of the minimum was more irregular, still it confirms the general law, in most respects. The minimum temperature for the same month began on the 3rd in Arkansas, Tennessee and Michigan; on the 4th in Florida, Alabama, Mississippi, Louisiana, Georgia, South Carolina, North Carolina and Ohio; on the 7th in Kentucky and Indiana; on the 9th in Pennsylvania; on the 10th in New Hampshire, Delaware, Maryland and Virginia; on the 12th in California, Montana and Colorado; on the 13th in Utah; on the 14th in Texas; on the 16th in Nebraska; on the 18th, in Minnesota, Wisconsin, Iowa Illinois, Missouri and Kansas; on the 23rd in Vermont, New York, Massachusetts and Rhode Island; on the 24th in Maine and the District of Columbia; on the 25th in Connecticut; and on the 26th in New Jersey.

The groups on the 18th and 23rd were in accord with the progression, if some of the others were not. Further observations may be more regular.

An official report shows that in May, 1870, there were 836 miles of telegraph in actual operation in the Argentine Republic, while 1,000 miles more were in construction. Wires are being carried across the Andes to Chili, and a connection is also to be established with Brazilian and other lines.

One of the strong brick Martello towers at Dimchurch was blown down recently by the Royal Engineers, with a charge of 196 lbs. of gun-cotton.

It is believed that the principal preservative substance used in embalming the mummies of Egypt was carbolic acid in the crude state.

IRON AND STEEL NOTES.

REVIEW OF THE IRON TRADE, 1870–71.—The outlook for 1871 is somewhat mixed and not altogether free from doubt. Our rail mills are most of them supplied with orders enough to occupy them some little time yet. There are, however, others who are open for contracts, and moderate figures would be accepted. There is a notable lack of cash buyers, and there is danger that in the eagerness of competition safety will be overlooked and a load of paper and bonds accumulated, out of which may grow disaster at some future time. It is earnestly to be hoped, however, that an early cessation of hostilities, bringing with it a satisfactory peace, may restore business to its normal condition and obliterate the uncertainty which now hangs over the market.

NEW RAILS.—The import during 1870 has again been large, its proportions being even greater than 1869. During the early part of the year, and until the outbreak of the war, prices of foreign were on a steadily ascending scale, reaching their highest point in June, at which time everything pointed to a prosperous Fall with still higher prices, but the immediate effect of the outbreak of hostilities was to blast at once all such expectations, and the prices have for six months been on the decline, with considerable irregularity, according as the prospects of peace rose or fell. As the market now stands, the margin between foreign rails and those of American make is very wide, and should the war continue much longer, it is evident that the competition must soon become very severe. To meet this successfully, some considerable reduction in material would seem to be necessary even beyond what the reduced price of pig-iron affords.

OLD RAILS.—The demand for this class of imported material has been large and constant, and prices have advanced during the year from 36s., gold, to 39½ to 40s., with occasional sales at even higher prices. The consumption has been general, with, we think, considerable increase in the area over any former year. Hardly ever has there been any excess of supply, and there is probably no article entering largely into our manufactures which has met so ready a sale, evinced by the large import, which will probably reach nearly 110,000 tons in the aggregate. That this has proved a great boon to our rolling mills is unquestionable, and has neutralized, to a great extent, the inconvenience arising from the inadequate supply of puddled bars; and any increase of the duty, as at one time threatened, would have been a direct injury to such of our mills as are dependent upon the open market for material.

It will be observed that, notwithstanding the increase in the gold price, the equivalent in currency now ruling does not vary materially from that of last year at same time. At that time gold was 120 and rails 36s., equal to 43.20s., against present prices, 39s., and gold 110¾, equal to 43.19s., currency. In quoting these prices we refer to the figures current for DH in round contract lots, for forward delivery, the bulk of the sales having been made in this way. That this should exist in the face of a decline in the currency price of the article made from them is evidence enough of the utility of old rails as raw material. During the past month the demand has slackened materially, and but for the fact that the supply abroad is not plentiful, prices would have yielded. The low price of pig-iron has led many mills to increase the number of their puddling furnaces, and it is evident that the supply from these sources will displace old rails to a certain extent, unless the demand for new rails increase *pari passu*. This will be particularly the case with mills situated at a distance from the seaboard, upon which the inland freight bears heavily.

The price, in gold, of old rails, has been from $35 50 to $39.00 per ton, closing at the latter figure.

SCRAP IRON.—The year's trade has been, on the whole, unsatisfactory to importers, and less foreign scrap has in consequence reached the market. The range in prices from yard has been between $37 and $42.50, currency, most of the sales being at about $39 to $40. Our extreme figures were attained only for a short time during May, when the whole stock became concentrated in one or two hands. Scrap iron is always sold in currency, and our quotations invariably represent as near as possible yard prices, as the great variety in the quality of what is offered from dock causes considerable irregularity in prices. As a general rule, however, dock quotations rule from $1 to $3 below these from yard for selected lots.

PIG IRON.—Although the make of American iron has this year largely increased, yet the market has labored under an apparently chronic depression, and prices have declined steadily, month after month, until they have now reached a point below which it is declared they cannot go. Many furnaces of small capacity and disadvantageously situated will probably be blown out, and as the temptation to invest money in this department is not now very great, we will probably witness this year a pause in the onward progress, if not some retrogression in the out-turn of our furnaces. One good feature, however, is the smallness of the stocks, both in the hands of the furnace men and manufacturers, so that we enter the year with fewer burdens and more hope.

In Scotch pig the import has been on a smaller scale than last year, and at times our stock has been very much reduced. The alteration in the duty from $9 to $7 will, in consequence, have less effect, if it has not in a great measure been already discounted, so far as it may influence the prices of the stock now here. There has been, generally, a great scarcity of the best brands, leading to extreme prices being sometimes paid for such, whilst inferior brands would, at the same moment, be difficult of sale. Bessemer pig, so called, has formed a large proportion of our imports the past 3 or 4 months. These have consisted mainly, if not wholly, of the Cumberland hematites, from the Workington, Harrington, Barrow and West Cumberland furnaces. These have been found by experience to be the most suitable irons for the Bessemer process, and the increasing demand for and large extension of the manufacture of steel rails will lead to a large consumption of these brands.—*American Railway Times.*

EXPERIMENTS ON STEEL.—For some time past a committee of civil engineers has been engaged in testing the resistance of steel produced by several of the principal manufacturers to tension, compression, transverse strain, and torsion (the necessary experiments having been made by Mr. David Kirkaldy under the instructions of this committee), and the results have now been published. Both funds and material were willingly

placed at the disposal of the committee, and every care was taken that the samples tested should represent the best marketable quality of steel ordinarily made by each of these manufacturers. The results obtained, both with Bessemer and crucible steel, are recorded in a series of elaborate tables, which will prove of the utmost utility to those employing that metal for constructive purposes. Tested by tension, the breaking stress of hammered Bessemer steel, such as is used for tyres, varied from 29.06 tons per in. to 40.71 tons per in.; hammered Bessemer steel, such as is used for axles, varied from 28.86 to 36.80; hammered Bessemer steel, such as is used for rails, varied from 28.51 to 35.68; rolled Bessemer steel for tyres could bear a breaking stress of 32.09 tons per in.; for axles, 32.22; and for rails, 30.74 and 32.61 tons per in. respectively. The Bessemer steel was in no material degree inferior to crucible steel; for with hammered crucible steel for tyres the breaking stress varied from 30.69 to 40.57; for axles, from 35.72 to 48.13; for rails, 38.14; and rolled crucible steel for axles gave 30.62 tons per in. breaking stress. The ratio of the yielding to the breaking stress is in round numbers from two-thirds to three-quarters.

The committee has also been favored by the Secretary of State for the War Department with a statement of a series of experiments made for the purpose of ascertaining the additional tensile strength resulting from tempering steel in oil and various temperatures, by the officers in charge of the Royal Gun Factory. A record of these is given in the book, as well as of some further experiments on tension and compression of long bars, and for ascertaining the amounts thereof by measuring directly from the bar in order to obtain very accurate results. As to the amount of reliance that may be placed upon the experiments, it need only be stated that the committee consisted of Messrs. W. H. Barlow, George Berkley (who has very ably performed the duties of secretary), John Fowler, Douglas Galton, C. B., and J. Scott Russell, whilst the actual experiments were made by Mr. D. Kirkaldy, to give the fullest confidence that every detail has been carried out with the utmost care and ability. The committee take the opportunity to invite gentlemen who have made careful experiments upon the properties of steel to favor them with the results, and it is cordially to be hoped that the invitation will be freely responded to.—*Mining Journal.*

Smelting Furnaces on a New Principle.—We learn from our Western exchanges that the Union Pacific Railroad Company has built several large iron furnaces for smelting the Wyoming Valley ores, on a new and somewhat ingenious principle, invented by the foreman of the Company's shops. In these furnaces the ordinary fan blower is dispensed with, and the blast of air is obtained by injecting jets of steam into the interior of the upper portion of the furnace. The vacuum thus created draws a blast through the fire with tremendous force, securing all the heat needed to smelt the ore, which does not fuse readily. The furnaces already built on this plan have been running very successfully for several weeks, and others are in course of erection. Foundries are also building, and the Company expects soon to supply itself with all the castings it requires, at a cost much below that at which they have heretofore been obtained from Missouri and the East. The plan of creating a blast of air by means of an ascending column of steam, is not a new one; but its application to smelting furnaces has not, so far as we know, been before attempted, and the improvement thus obtained over the fan-blower may be found important as simplifying the machinery of blast furnaces.—*Iron Age.*

Rolling Railway Axles.—A communication was recently made to the British Association upon a method for shaping railway axles by rolling pressure, instead of by hammering, the result being accomplished in two minutes, instead of half an hour, as required by the usual method; the axle at the same time being not only superior in quality, but more uniform in size, and of course capable of being produced more cheaply. The machine consists of three rollers regulated so as gradually to press more closely together, thus reducing the diameter of the bar, and extending its length until shaped to the size required. Axles of any length can be rolled in this manner with collars at any part. The rollers are geared to revolve all in the same direction, their friction imparting motion to the axle. It was thought by the author of the communication that the rolling process would tend to obviate those flaws in axles which frequently cause disasters on railways.

RAILWAY NOTES.

Continuous Freight Traffic over Lines of Different Gauges.—Mr. Alfred C. Pope, of Binghamton, in a recent letter, says:

In order to facilitate the transfer of trucks in Mr. Noyes' arrangement, I would suggest that the trucks of the cars operated upon should rest upon *turn-tables*, fitted with tracks of the different gauges.

By this means the rejected truck could be disposed of without interference with that which takes its place.

This arrangement for the transfer of loaded cars is apparently the quickest, and certainly safer than the only method now in use. With a yard properly arranged, the transfer can be made in ten minutes with ease and safety.

The first outlay, and the expense of running, need not be heavy, and the great *desideratum*, that of each transportation company keeping the control of its rolling stock, could be perfectly carried carried out.

By this means also the return freight could be expeditiously managed, and if, at any time, it should be desirable to accumulate a large amount of freight for a particular road, it could be readily done, and yet be in shape to be forwarded at a moment's notice.

Hardening of Rails.—At Demitoff's works in Salda Nischne, some years since, it was accidentaly discovered that ordinary iron rails gain essentially in hardness by sudden cooling. Want of room in the mill necessitated the removal of a part of the rails, while still red hot, to the outside of the building where the ground was covered with snow. Subsequent experiments made by the Commission appointed by the Government to test the rails, revealed the fact that the rails thus suddenly cooled were harder than those gradually cooled, and since this time all the mills in Russia harden their rails by cooling in water.

In the works of Von Putilow, near St. Petersburg, rails with mild puddled steel heads are allowed to cool in the air, until they cease to be luminous, before immersion in water; but in all other mills, rails of hard iron are plunged into cold water immediately after leaving the saws.

As these rails are found perfectly reliable in Russia, where the temperature in winter is often 40 to 60 deg. below zero, there can be no question as to their applicability elsewhere.

The danger of fracture in good hardened rails depends obviously only on the *degree* of hardness, and this depends on the amount of carbon present in steely irons, and on the temperature at which the hardening is effected, and there can scarcely be any tenable ground why rails should not be hardened while many other articles are, in which fracture is equally to be feared.

The hardening effected by sudden cooling is indisputably less dangerous than that imparted by phosphorus, and in case of iron free from impurities, when we compare rails hardened on the one hand by the addition of carbon (approaching steel in composition), and on the other by sudden cooling, the advantage of safety would undoubtedly be in favor of the latter—to say nothing of the expense of manufacture.

In this connection may be mentioned that at Salda Nischne, and also at Wolkinsky, a photometer, the invention of Director Palanow of the former works, is in use to determine the temperature of the rails after leaving the rolls, by the amount of light emitted, so that the ends may be sawed off at a constant temperature, thus securing perfect regularity in the length of the finished rails.—*Translated for the Bulletin of the Iron and Steel Association, by Thomas M. Drown.*

NARROW GAUGE RAILWAYS IN MASSACHUSETTS.—A joint committee of the Massachustts Legislature have reported a bill to authorize the construction of narrow gauge railways. The bill provides that any branch railway hereafter constructed in this State may adopt a gauge of 3 ft. on the existing gauge or 4 ft. 8½ in., and no other gauges shall be used in this State. Any association of persons, a majority of whom shall be citizens of this commonwealth, and all of whom shall be citizens of the United States, is authorized to locate, construct, maintain, and operate, within the limits of any town in this State, a branch railway with a gauge of 3 ft., with suitable tracks, stations, and equipage; provided, that at a meeting of the legal voters of said town, two-thirds of such voters shall authorize the construction of the road. Upon recording articles of association the association shall become a body corporate, with all the powers and privileges, and subject to the duties and liabilities affecting railway corporations. Any railway corporation now established may locate, and may maintain as a part of its railway system, one or more narrow gauge branch roads, provided the county commissioners where the road is to be located determine that the public convenience or necessity requires it. The bill also makes provision for the transfer of freight from the narrow gauge roads to the existing roads.

IMPROVED LUBRICATOR.—A correspondent in Cleveland writes us that he expects soon to offer to railroad companies "a device that will be very acceptable, yet not entirely new, but almost invaluable in its economy, comfortable character, and adaptation to uneven and curved railroads." He says that he has certificates from prominent railroad men stating as the result of experiments that *one-half* of the expense of lubrication has been saved by it, and hot boxes entirely avoided, and that the saving of time, labor, brasses and motive power has been scarcely less than the saving in oil.

Having thus excited our curiosity, our correspondent makes no attempt to satisfy it, but leaves us and our readers to guess by what means these desirable effects are attained.—*Railway Gazette.*

THE ELECTRO-MAGNETIC BRAKE IN NEW ENGLAND.—The Massachusetts Railroad Commissioners in their last annual report, while discussing the Providence & Worcester Railroad, say:

"Upon some cars of this road Olmstead's electric brake has been applied, which may be put in action on any car by itself, or on all the cars on the train at once, from the engine. The power is furnished by a battery in each car; the electric action keys up a loose wheel on the axle, and this winds up a chain attached to the brake. The advantage of this brake over Creamer's, or any other acting by a spring, is that it is always ready for action, and does not need to be wound up every time it has been used. In the experiments witnessed by the commissioners, it did not appear to have any superiority in quickness of action over the common hand brake. The Superintendent of the road, however, stated that this brake had been in use on five cars for two months and had given good satisfaction; that it would stop a train in thirty-three seconds in running not much more than the length of the train."—*Railway Gazette.*

STEEL TIRES UNDER BRAKES.—Mr. T. Rochussen, of London, writes as follows to the London "Engineer" relative to recent accidents on English railroads caused by the breaking of a tire of a wheel:

"Although, during the last twenty years, steel was indiscriminately used wherever practicable in the permanent way and rolling stock of Prussian railways, and its value recognized long before it found root in English practice, it has always been understood that cast steel tires should not be applied to wheels running under brakes, and for this reason: The cast-steel tires, when checked by the brake and skidding upon the railway, get very hot by friction; in pulling up in a pool of water, a heap of snow, or even in a keen draught of wind, a cast-steel tire may, under such circumstances, get a hard chill or brittle temper, and, being so injured and deprived of elasticity, it may break at any time, either while running free or under a brake, and that without giving previous sign of existing danger.

"I may add, speaking from my own knowledge of most of the large steel works in Prussia, that, in contracts for material, manufacturers distinctly stipulate that no guarantee is undertaken for cast-steel tires or disc wheels if at any time used under brakes. The only material admissible in such a position is good fine-grain iron approaching in crystallization to very mild puddle steel, which does not temper by sudden cooling; or, if a bias in favor of steel must be over-indulged, the cast steel should be made especially for the purpose, so as not to contain more carbon than wrought iron, with which it would become identical. Such a tire could be safely bolted to the wheel, and this process would, in the Hatfield accident, have been

less dangerous than the Beattie fastening, which, although designed to hold the tire on to the wheel even when the tire should burst, in this instance failed to answer its purpose.

"The Prussian Board of Trade prohibit the use of cast steel-tires under the brakes of the mail carriages, which, on an average, weigh 17½ tons, and form part of nearly every passenger train throughout the country."—*Railway Gazette.*

NORTHERN PACIFIC.—Work was begun in July last on the eastern portion and the money provided, by the sale to stockholders of $6,000,000 of the Company's bonds, to build and equip to the Red River—233 miles. Several thousand men are at work, and about the 1st of August next this important section will be in operation. In the meantime orders have been sent for the commencement of work on the western end, and the work will be pushed, both eastward and westward, with as much speed as may be consistent with solidity and economy.

The road runs through the following counties: St. Louis, Carlton, Aitkin, Crow Wing, Cass, northern border of Todd, northern part of Otter Tail, western part of Becker, and northern part of Clay. It crosses the Red River a few miles north of Georgetown, and the Mississippi at Brainard, 13 miles north of Crow Wing.

At Thomson, 22 miles from Duluth, it connects with the Lake Sup. & Miss. R.; and near Cartridge River, with the branch of the St. P. & P. (when extended). Branch lines will be built north and south, to drain the entire region north of lat. 42° and render the future construction of additional east and west lines within that belt unnecessary.

Through the first 100 miles from Duluth the road passes through timber; the remainder of the distance to the Red River is alternate timber and prairie—a fine agricultural country.

The present equipment is only intended for the work of construction. None of the gradients are heavy through Minnesota, the general face of the country being level.

Concerning the purchase by the Northern Pacific R. Co. of the two lines of the St. Paul & Pacific R., the announcement in the N. Y. *Tribune* recently, was an authentic statement of the transaction as closed. The Northern Pacific R. Co. purchased from E. D. Litchfield, of London, the main and branch lines of the St. P. & Pac. R.—about 800 miles in length. Mr. Litchfield is to complete the main line to Breckinridge. From this point it will extend to the Missouri. The extension of the branch to Pembina and the British boundary line will be commenced immediately. The principal officers of the St. Paul & Pacific retain their positions. The effect of this purchase is practically to consolidate the two roads, and thus give the Northern Pacific a double eastern terminus—one arm reaching to St. Paul, there tapping the commerce of the Mississippi valley, and connecting with the Illinois and Eastern systems of roads; the other extending to Duluth, where it meets the commerce of the great lakes and the St. Lawrence. The consolidation also removes all hurtful rivalry between competing interests.—*Chicago Railway Review.*

COMPARATIVE COST OF SUPERSTRUCTURE FOR DIFFERENT RAILWAY SYSTEMS.—We make the following extract from a very neat circular issued by M. Baird & Co., of the Baldwin Locomotive Works, of Philadelphia.

The circular presents six photographs of as many different styles of narrow gauge locomotives.

All needful statistics of weights, dimensions, cost, and power are neatly tabulated.

The weights and capacities of the different classes of cars are given in similar manner.

The following is the extract referred to:

The following are comparative estimates of the cost of a mile of single track, properly proportioned for each gauge specified:

1st. For 4 ft. 8 in. Gauge.—Rail 55 lbs. per Yard.

87 tons of rails, @	$70 00 per ton	$6,090 00
400 rail splices, "	1 00	400 00
5,500 lbs. spikes, "	5	275 00
2,640 cross ties, "	80	2,112 00
2,000 cubic yards gravel ballasting, @	50 cts.	1,000 00
Laying 1 mile of track		500 00
Total		$10,377 00

2d. For 3 ft. 6 in. Gauge.—Rail 35 lbs. per Yard.

55 tons of rails, @	$75 00 per ton	$4,125 00
340 rail splices, "	60	204 00
3,520 lbs. spikes, "	6	211 20
3,520 cross ties, 5 ft. long, 5 x 6 @	40 cts	1,408 00
1,200 cubic yards ballasting gravel, @	50 cts.	600 00
Laying 1 mile of single track		350 00
Total		$6,898 20

3d. For 3 ft. Gauge.—Rail 30 lbs. per Yard.

47½ tons of rails, @	$75 00 per ton	$3,562 50
330 rail splices, "	50	165 00
3,520 lbs spikes, "	6	211 20
3,520 cross ties, 5 ft. long, 5 x 6 in., @	30 cts.	1,056 00
1,000 cubic yards ballasting, @	50 cts.	500 00
Laying 1 mile of single track		300 00
Total		$5,794 70

4th. For 2 ft. 6 in. Gauge.—Rail 25 lbs. per Yard.

40 tons of rails, @	$75 00 per ton	$3,000 00
330 rail splices, "	50	165 00
3,520 lbs. spikes, "	6	211 20
3,520 cross ties, "	25	880 00
1,000 cubic yards gravel ballasting, @	50 cts.	500 00
Laying 1 mile of single track		250 00
Total		$5,006 20

5th. For 2 ft. Gauge.—Rail 20 lbs. per Yard.

31½ tons of rails, @	$75 00 per ton	$2,362 50
330 rail splices, "	45	148 50
3,520 lbs. spikes, "	6	211 20
3,520 cross ties, "	20	704 00
750 cubic yards ballasting, @	50 cts.	375 00
Laying 1 mile of single track		250 00
Total		$4,051 20

Comparative cost per mile of each Gauge.

Cost of 4 ft. 8½ in	track	$10,377 00	standard road used.		
" 3 " 6 "	"	6,898 20	reduction	33½	p ct.
" 3 "	"	5,794 70	"	44	"
" 2 " 6 in.	"	5,006 20	"	52½	"
" 2 "	"	4,051 20	"	60	"

TRAIN SIGNAL LIGHT.—A signal light, to be attached to the rear of trains, invented by two officers of the Little Miami Railway, has lately been tested on that road. It is thus described: "In the centre of the roof of the rear car of the train, over the rear axle, is placed a square lantern, with alternate panes of red and white glass.

The lantern is connected by means of a shaft with one of the axles in such a manner that eight revolutions of the axle produce one of the lantern. When the car stops, the lantern of course ceases to revolve. Upon each side of this main lantern are two others, also connected with the axle in such a way that when the train is moving forward a solid red light is displayed, and if backing, a solid green light. The engineer of a train coming up in the rear can thus tell, by observing these lights, whether the train before him is moving or at a stand-still, and if moving, in which direction.—*American Railway Times.*

THE iron road will enter China to stimulate the production of her multitudinous industries as a basis for enlarged commerce. Recently, the first railroad in China was formally tried by Li-Hung-Chang, Superintendent of Trade and Viceroy of the province of Chili-hi, on his taking charge of the Tien-tsin arsenal, a tramway of some three miles, extending around the establishment. This will, it is inferred, be the parent of a railroad system ultimately as grand in its distances as our own. Li expressed himself as much pleased, and evinced that his ideas are going beyond the "Pekin cart."

WROUGHT-IRON RAILWAY SLEEPERS.—Mr. Richard Gammon, of Westbury, has patented a new railway sleeper, which is likely to supersede the whole of those at present in use, expecially in tropical countries. The constructors of our railways in India experience the greatest difficulty in making and maintaining the permanent-way. The dry-rot, and those pests of India—the white ants—destroy everything. Sleepers sent from England creosoted and "pickled" are not protected from the influence of the sun and vermin, and seldom or never last more than three years. It was necessary, therefore, to find a substitute, something not only impervious to the attacks of the insects, but which might be made in this country perfect and ready to be laid down wherever they should be required. Mr. Gammon's sleeper is made up of a number of webs and plates of rolled iron, riveted together, and pierced with bolt-holes for the chairs. This saves about two-thirds of the labor in laying, and leaves but little work to be done by native or other labor. The direct cost is not more than 1s. each above that of the best wooden sleepers, and they are calculated to last ten times as long in tropical countries, and three times as long in Europe. Many eminent engineers and railway contractors, who have examined them, believe they will be the railway sleepers of the future. At all events, the invention is highly ingenious, and likely to supply a great want.

INJECTORS ON LOCOMOTIVES.—Noticing a statement in an editorial in the "Railroad Gazette" some weeks ago, that we knew of no locomotives in this country running with injectors alone, "Engineering" says:

"If the American locomotive superintendents have yet not tried working these engines with injectors alone, it is time that they commenced. There are hundreds of locomotives without feed pumps running in this country and on the continent, and hundreds of them with one injector, and the cases of failure with engines so fitted are but exceedingly few, compared with those which take place where pumps are used."—*Railway Gazette.*

LOCOMOTIVE WATER-TROUGHS.—Troughs for supplying locomotives with water while in motion have been laid on the Pennsylvania Central Railway, one at Derry and another near Johnstown. The troughs are 18 in. wide, 6 in. deep, and 1,500 ft. long. The scoop let down from the locomotive will take up water at the rate of 2,200 gals. from each trough.

ORDNANCE AND NAVAL NOTES.

IRON SHIP-BUILDING.—The Pittsburgh "Commercial" says: It cannot be denied that Pittsburg has, in her existing facilities for the production of iron, unparalleled advantages for the building of iron vessels. During the rebellion many thousand tons of armor plating for the ironsides and others of the best iron-clads of our navy were successfully manufactured here, at a fair profit, in competition with the bids of Eastern establishments, which had the advantage of railway transportation over the mountains in their favor. In 1864 our Pittsburgh mechanics had contracts also for the construction of four iron-clads for the navy of the United States.

Thirty-one years ago, in the construction of the river steamer Valley Forge, our mechanics made their first experiment of an iron hull, and had the owners of the Valley Forge proceeded to remedy the defects of her construction by another, instead of condemning the material, it is probable that most of the Ohio steamers now in existence would have been made of iron.

Over twenty years ago two revenue cutters, now, we believe, in service on Lake Erie, were built at the Fort Pitt Works, and within a few weeks an iron propeller has been launched, to be employed on the Southern coast. We mention these facts, not as novelties to our home readers, but for the inference that what has been done successfully in the past, may be emulated on a larger scale in the future. The enterprising concern which built the propeller last mentioned, is engaged in the construction of another, and we can assure our seaboard readers it is not the only one that is prepared to receive their orders for either coasting vessels or ships. We are glad also to know that one of our most successful steamboat owners has taken in hand to build, at Pittsburgh, a first-class iron steamboat for the Western waters. These beginnings, small though they be in comparison with the vast field of enterprise which is opened by the present and prospective demand for iron vessels of all sorts, will eventually win for Pittsburgh a share of the business of their construction. Meanwhile, while our shops are "waiting for orders," other cities capable of a more comprehensive view of the future, will have established themselves as the great centres for iron ship-building; Pittsburgh has accomplished grand results by the individual energy and enterprise of her citizens through a long series of years. We are proud of our pre-eminence in the manufacture of iron. Nevertheless, in this our chief production, a dozen petty towns north and west of us have, by means of associated capital, done more relatively to their population and advantages, within the short space of 2, 3, or 5 years, than Pittsburgh in 40 years. Our rival cities in the West, St. Louis and Cincinnati, understand this, as witness the progress made by the former

in the production of iron, and the new enterprise organized in the latter for the construction of iron steamers. If a company shall be successfully established in Cincinnati, with adequate capital to engage in this business, Pittsburgh will find, when too late, that a golden opportunity has been allowed to pass, and her iron interests will suffer a loss which can never be retrieved. If, on the other hand, her manufacturers and business men, by associating their capital, engage at once in the enterprise, her supremacy will be maintained. In addition to the requirements of the merchant service and the Western rivers for iron vessels, a similar demand must be met in the construction of an iron navy for the United States Government. The construction of war steamers in the Government ship-yards must soon be abandoned. The inferiority of vessels built at Government ship-yards, their failure to answer the reasonable expectations of the Navy Department, and the fact that better can be had by private contract at a far less price, is no longer denied, and it only remains to overcome the official reluctance to change. Other nations have abandoned the costly and damaging system of Government construction, and in this, as in the change from wood to iron, the United States, which should have led, must follow. There are in the British navy 97 iron vessels, of which no less than 80 were built in private ship-yards, and only 17 in the yards of the Government.

The consumption of iron in Great Britain for the year 1870, in the construction of vessels, was 250,000 tons. President Lincoln, during the rebellion, recommended the establishment of a naval depot for the construction of iron vessels at some point on the Western waters. For the reasons given above, we do not believe such a depot of construction will ever be established, but for the same reasons which probably led to the recommendation, we believe that the Western waters will be found to be the best region for the reconstruction of the United States navy—and Pittsburgh is the place on the Western waters with most advantages for the business. Whether Cincinnati or St. Louis shall, by superior enterprise, overbalance these advantages or not, depends upon the apathy or the enterprise of our manufacturers and business men.

With some men, the fact that any scheme involving the investment of money is urged upon the ground of a public benefit or necessity, at once closes up their ears and their pockets. Happily this scheme of a great iron ship-yard at Pittsburgh has the intrinsic merit of presenting the strongest temptation in the certain profit which must accrue to the investment. The more carefully the subject is investigated, the more attractive it will appear as a mere business operation. And this being the case, we feel the strongest assurance that if a few of our leading men will organize the ship-building company, all the capital needed will be promptly furnished, and the stock will soon command a premium.

NAVAL ARMAMENTS.—Captain A. E. Scott, R.N., recently delivered a lecture at the Royal United Service Institution upon the subject of naval armaments. The lecturer touched upon a very wide range of subjects, and the lecture was somewhat desultory and disconnected, for which the gallant captain excused himself upon the grounds of his being an over-worked man. He, however, advanced some good points which were appreciated by an attentive audience. After numerous quotations from several of the daily and other papers and comments upon their remarks, Captain Scott touched upon the question of naval drill, observing that on board the Prussian ships the drill was most perfect, and that it required improving in our own navy. He then discussed the probabilities and possibilities of an invasion of England, to meet which he observed we require a greater number of more useful vessels. The object being to prevent the enemy landing, we should have a number of gunboats of the Staunch class, mounted with 18-ton guns, which would place our defences in a high state of efficiency. By uniting our bays and creeks, and by further operations inland so as to render good the approaches for our volunteers, England would be rendered impregnable. The mounting of our naval guns then received a large amount of consideration at the hands of Captain Scott, who has devoted many years to the subject, and who has done real service in perfecting naval gun carriages. Captain Scott's system is now applied on board the Hercules, the Sultan, and other vessels, the highest testimony being borne to its efficiency by gunnery officers. The effect of the introduction of Captain Scott's training gear on board the Northumberland was, he stated, to save the annual expense to the nation of 45 men who were required as extras for that vessel, but whose services were superseded by the training gear in question.

Captain Scott then referred to his turn-table arrangement for working guns, noticing, at the same time, the difficulty he had experienced in getting the Government to adopt his plans, although their adoption had proved them to be so eminently successful. Moreover, the gallant captain further pointed out how that, for all his years of labor and heavy outlay, the Government had not in any way rewarded him, nor had paid one farthing of his expenses. The lecturer then went on to point out what, to him, appeared to be difficulties in the way of fighting turret ships, after which he glanced off to the torpedo question, paying a well-merited tribute to the efficient and seamanlike character of the Harvey torpedo. These weapons, he observed, would probably turn the tide of battle in favor of those nations who employed them. Doubling back upon the turret-ship question, the author complimented Mr. E. J. Reed upon his raised breastwork, which will greatly enhance the value of monitors. Such vessels could be used as hospital ships, and could carry torpedo boats, and doubtless would do so in the future. The question of breech-loading *versus* muzzle-loading guns then came in for notice, the lecturer being, rightly, of opinion that the merits of the breech-loading system were over-estimated. If torpedoes were used in future actions—as they undoubtedly will be—Captain Scott observed that ships would require guns to keep them off. In view of this he had designed a new carriage for 20 and 40-pounder guns, and with which we understood the Sultan and the Lord Clyde had been supplied. The object was to arm our iron-clads all round with these guns, which were for rapid use against torpedo boats and other similar craft. But with all the best mechanical arrangements, the lecturer observed that England's supremacy could not be maintained unless we had more intelligence in some of the men of the Royal Navy, but which the present pay of £30 or £40 per annum would never

secure. A vote of thanks was accorded to Captain Scott at the close of his lecture, which, by the way, he stated was only a first instalment on the subject. The second is to follow, and we trust the gallant lecturer will find time to digest and organize his matter between the present time and the delivery of the lecture, for by so doing he will greatly enhance the value of his discourse.—*Engineering.*

ENGINEERING STRUCTURES.

THE DARIEN SURVEY.—All doubts of the practicability of constructing a ship-canal across the Isthmus of Darien have been dispelled. Surveys made from the Pacific coast during the last month have proved the Atrato-Tuyra route to be perfectly feasible; and I will venture to say that if, within the limits of New York State, a ship-canal were to be cut through a country precisely similar to that which we find here on the Isthmus of Darien, it would be open for navigation in less than 8 years. Since the date of my last letter from the Atrato river, everything has been going on well in the Gult of Darien. The Guard still lies at her old anchorage near the entrance to the Gulf, and the Nipsic makes occasional trips to Aspinwall for the mails or provisions. Good progress is making in the hydrographic surveys, and the final chart of the Gulf will be a valuable contribution to the Bureau of Navigation. Chief Engineer Barnes is still in the interior, pushing on as rapidly as possible over the Paranchito route towards the "divide."

SURVEYS FROM THE PACIFIC SIDE.—At present the attention of Commander Selfridge is directed particulary to the surveys on the Pacific side. On February 5th, a party joined the United States steamer Resaca, Nathaniel Greene Lieut.-Commander, which had been detailed by the Navy Department to join the Darien Expedition in place of the Saginaw, recently wrecked on her voyage to Panama. The voyage down the coast was an exceedingty interesting one; the scenery though not grand is very picturesque and beautiful. In our course were the Pearl Islands, which in former years yielded vast quantities of the gems from which they derive their name, but a disease has lately attacked the pearl oysters, and, in consequence, diving for them has almost entirely ceased. We entered the Tuyra river through the Gulf of San Miguel, which in many ways is admirably suited to the Pacific terminus of the canal. The river Tuyra is upward of a mile in width, and in its waters the largest ships may float up to a point about 6 miles above Chepigana; the Resaca anchored about a mile above the latter town, in the centre of the stream. On the day of our arrival, Friday, February 17, Commander Selfridge left in a whale-boat, with 4 days' provisions, to make a reconnoissance up the river. During his absence a provision-camp was established in the woods on the northerly shore of the stream, an observatory erected, and a tide-gauge placed in position. The tide here has a rise and fall of from 15 to 20 ft., and the current in the river runs from 3 to 4 miles per hour. The banks are formed of a slimy clay, with boulders and shingle of quartz and flint.

After an absence of 3 days Commander Selfridge returned to the ship, having explored the river as far as Pinogana. He found that it did not narrow down until he passed Alligator Island, 18 miles from the ship; thence upward its course is so winding that, while the distance from Chepigana to Pinogana, travelling by boat, is about 45 miles, astronomical observations show that a straight line connecting the two points would be only about 22 miles long. From Chepigana to the junction of the Tuyra and Chuquanaqua rivers there is not a settlement of any kind. Primeval forests are on either bank of the river, and these, at night, are frequented by vast numbers of monkeys, which fill the air with the most piercing shrieks. The only signs of life by day are the alligators and herons. The former are always seen at low water sunning themselves upon mud-banks, from which, when disturbed, they glide into the water with distended jaws, and sometimes they stayed about the boat for several minutes. About 2 miles above the junction is the town of Santa Maria; 7 miles further on is Mollineca, from which Pinogana is only 3 miles distant. Throughout its whole course the river runs between perpendicular banks from 10 to 20 feet in height. Not a hill of any description is met with, notwithstanding the fact that the present maps of the country represent it as traversed by range after range of high mountains. The country is apparently perfectly level, but it undoubtedly has a slight elevation toward the interior. For agriculture it is remarkably good, but owing to the indolence of the natives it is unimproved. A few days after the return of Commander Selfridge he started out with the first surveying party, which is under the military command of Master Eaton. All work connected with the survey is under the direction of Assistant Engineer Duvoll, assisted by Ensign Wiley. The party, as it left the ship, consisted of 27 persons, all of whom embarked on the steam launch, which had in tow a large flat-boat, with one week's provisions. At Pinogana the launch could go no further on account of shoal water. The party, with provisions, were stowed away in 3 large canoes, in which they made the ascent of the river as far as its junction with the Cue. There a hut was built in which to stow the provisions, and, after a day or two of rest, the survey began. Running a line of levels in this county is a slow process. The machetta men can cut only about 3,000 ft. per day, and they must, of course, always remain in advance of the instruments.

OTHER ROUTES UNDER EXAMINATION.—Mr. Duvoll is instructed to proceed up the Cue valley until he reaches the "divide," or meets the party of Mr. Barnes from the other side. Every night signals are to be made and firearms discharged by both parties, so that, if within hearing distance, they may come together. In regard to the Cue route, I am able to state, from information received from Commander Selfridge, that it is one over which a white man has never passed. Gorgoza, who explored the Isthmus some years since, never crossed the "divide." He went only to the Indian village of Paya, after which he retraced his steps to San Miguel Bay. The Cue river is a tributary of the Tuyra, and runs through a valley which bears its name. A route up this valley, across the "divide," will connect with the Paranchito, which, by personal observation, is known to be much lower than the Cacarica. The two parties will probably meet in the course of 2 or 3 weeks, and the object for which the Darien Expedition was organized will be accomplished. The length

of the proposed canal is less than 50 miles. About 30 miles of it will be through a country which is apparently "dead level." The greatest elevation in the remaining 20 miles will not be over 150 ft., and it is believed that a point in the "divide" may be found where it will not be more than 75 or 100 ft. in height. A report having reached us that it is only a 6 hours' walk from the Naipipi river, which flows into the Atrato, across a range of hills 400 ft. high to the Cupica river, which empties into Cupica Bay, Limon Bay, and the Pacific Ocean, Commander Selfridge went in the Resaca to examine the route. No one has much faith in the statements of our native informants, and the examination is made in order to settle the thing one way or the other. Before leaving the Tuyra Master Kelly was sent to Pinogana with 6 weeks' provisions for the surveying party in the interior. His instructions are to dispatch 600 lbs. of food weekly to the junction of the Cue river; thence it will be carried in "packs" to the end of the line.—*N. Y. Tribune.*

PROPOSED TUNNEL FROM BOSTON TO EAST BOSTON.—The necessity for freeing the ferries between the above places is rather doubtful. A design for a tunnel between East Boston and the city proper has been prepared, under the direction of Major-General Foster, of the United States Engineering Department. The submarine portion of the tunnel is to be constructed of brick, arch-shaped, laid in a trench and enclosed in a wrought-iron skin or tube. It is proposed to lay two of these tubes, each having an outside diameter of 26 ft. and an inside diameter of 21 ft., so that horse-cars and teams, as well as foot passengers, can move each way at the same time. Leading to these tubes on either side are to be archways of brick. The Boston proper entrance to this tunnel or archway is to be on North street, near its junction with Garden Court street; the East Boston entrance will be from Maverick square. The estimated cost of construction is as follows:

Excavation	$328,723 70
Back-filling	54,309 86
Masonry	724,348 50
Iron work	645,483 45
Timber work(sidewalk)	11,772 00
Paving	43,175 00
Laying of iron tube by submarine (310 sections)	165,000 00
Total	$1,971,062 01
Contingencies (10 per cent.)	197,107 99
Grand total	$2,168,170 00

The present cost of the ferries is about $1,000 per diem, or say $350,000 per annum. The interest on the cost of the 2 tunnels, at 6 per cent., would be only some $125,000 yearly, showing a saving of some $225,000 yearly by the construction of the tunnel.

CONCRETE AND IRON BRIDGE.—A new bridge erected for Sir Shafto Adair, from the designs of Mr. H. M. Eyton, of Ipswich, over the Waveney, at Homersfield, England, has been recently tested. In designing the bridge advantage was taken of the principle of Messrs. Phillips' patent fire-proof construction, a system in which all the ironwork is completely embedded in Portland cement concrete. The bridge has one arch of a clear span of 50 ft., with a rise of 5 ft. 3 in The skeleton of the bridge is of iron, and this is entirely filled with Portland cement concrete, and rendered with Portland cement, thus forming one continuous beam, getting stronger every year, in addition to the iron skeleton, which is of itself sufficient to do the ordinary statical work of the bridge; the weight of concrete alone is over 100 tons. The spandrels of the bridge are relieved by a raised pannel, and in the centre is a casting of the Adair arms, taken from the old three-arched brick bridge. The first test applied was that of a five-ton road roller drawn by four horses. This was passed across several times, and not the least deflection was perceptible. Afterwards a heavy wagon, laden with sacks of flour, weighing altogether 6 tons, was passed over, and still, it is stated, no deflection could be noticed.—*American Railway Times.*

ROAD STEAMERS.—Notwithstanding the stupid restrictions on the running of steam carriages on roads, such as walking with a red flag in front of them, they are making progress. The recent severe frosts have put these steamers, which have lately begun to rise in public opinion, to a severe test. Happily, it is said, they have gone through it successfully. Mr. White, of Kettock s Mill, near Aberdeen, worked his road-steamer regularly throughout the frost. It runs between the mills and the town, a distance of three miles, part of which has a rising gradient of 1 in 10. Up this steep incline the road-steamer bravely drew a load of 7 tons, though the road was covered with solid ice. The wheels of these steamers are covered with india-rubber tires, and as india-rubber does not slip on ice, the steel guards are removed, and the engines do not slip. The question is a very important one as regards the practical value of the steamers, as they can now be used for regular traffic in very cold countries, such as Russia and Canada, where sledging is commonly employed. The india-rubber tires run over almost any kind of surface, and can consequently, it is believed, be used on the dry hot hands of India as well as on frozen roads.

Thompson's road-steamers are about to be brought into use in India. It is intended to run them between two stations in the Punjab, viz, Rawul Pinde and Jhelum, 68½ miles apart. The boiler is on the vertical principle, by which means a nearly uniform water level is maintained when either ascents or descents are being made, a thing in itself of great importance. The india-rubber tires are about 4½ in. thick, and flatten with the weight of the engine, thus giving great adhesion and elasticity on bad roads. The engine runs on 3 wheels only, and in this way a small wheel base is obtained and great facility given for steerage. This train will, on ordinary occasions, consist of one, and on extraordinary occasions of two, omnibusses, and will run the distance in 7 hours, inclusive of all stoppages. One omnibus will carry 20 first, 20 second, and 20 third class passengers, with 50 cwt. of mails and luggage, which will be sufficient for every day traffic. The steamers are well known in the streets of Edinburgh.—*Builder.*

The water works tunnel at Buffalo has been extended 60 ft. into the lake. The tunnel is to be 9 ft. in diameter and over 700 it. long.

NEW BOOKS.

TABLES OF LOGARITHMS AND ANTILOGARITHMS TO FIVE PLACES, with Marginal Indices for Instant Reference. By E. ERSKINE SCOTT, Actuary and Public Accountant. C. & E. Layton.

This book is the earliest of a class. It should be called "ledgered logarithms." The phrase "marginal index" does not convey that protruding margin, which, like the *ledgering* of the index of a ledger, enables the searcher to turn to his letter at once. And the tables of logarithms and antilogarithms are separate, each having its ledger. But another new feature presented by this table is that it gives *every* 5 figures with their 5 figures of logarithm or of antilogarithm, so that there is no interpolation whatever. And, though not very important, the fifth figure is always correct.

For instance, we want the logarithm figures for 18463. In the common table, we *do dictionary* until we have found 1846, and we find 26623 with a tabular difference of 24. Our fifth figure is 3, and by a small head-multiplication we find 7 has to be added to 26623; this gives 26630. In Mr. Scott's table, we take 18 on the black ledgering (the antilogarithms have red), turn up its page, and we see all that begins with 18; 18463 gives 26630.

Again, suppose we had wanted the primitive figures to 26630, we turn up the page by help of 26 in the red ledger, and 26630 gives 18463.

We have then logarithms without turning of leaves or calculation of proportional parts. But where is the use? Can we not whip off a logarithm quite as quickly in the common way? No doubt, if logarithms were never wanted more than one at a time, we might as well mount a siege-gun to shoot a solitary franc-tireur as set Mr. Scott's table going. But when a job of calculation requires scores or hundreds of logarithms, the saving will be very perceptible with practice. The use of the table may be entirely managed with the left hand, so that the pen need never be out of the right hand. This is something.

In the article "Tables," of the "English Cyclopædia," the ledgering is recommended; and, from some little trial, it is expected that no greater improvement has been suggested since Briggs first made his substitute for the Napierian form. If this assertion be incorrect, we should be glad to know what the intermediate process is by which it can be contradicted. We could say much on the subject, but to those who are not to use these tables, it would be unnecessary; and to those who are to use them, very unnecessary indeed.—*Mechanics' Magazine.*

A NEW MANUAL OF LOGARITHMS TO SEVEN PLACES OF DECIMALS. Edited by Dr. BRÜHNS, Director of the Observatory, and Professor of Astronomy at Leipzig. 8vo. B. Tauchnitz, Leipzig. 1870. D. Van Nostrand, N. Y.

The arrangement of these tables is in many respects similar to that of Bremiker's excellent edition of Vega's seven-figure logarithms. The type is larger and clearer than that of Bremiker, being of the same Old English form. We agree with the editor in preferring it to the Egyptian type of Schrön, the only serious objection which we should urge to it being the liability to call 6 or 9 by mistake a zero. For the first 6 deg. of the octant the sines, cosines, tangents and cotangents are given to every second, whereas in Bremiker only sines and tangents are given, and that only for 5 deg. For the remaining 39 deg. they are given to every 10 seconds. Wherever space allows, the proportional parts of differences are inserted in the margins of the parts. The arrangement of the pages in these 39 deg. is like that of Bremiker, except in putting sines and cosines in *adjoining* columns. The arrangement for the first 6 deg. is quite different from and is better than that of Bremiker. Extraordinary care, it is claimed, has been taken to secure accuracy in printing, and the logarithms of the circular functions were independently computed, as well as compared with established tables.—*American Journal of Science.*

MODERN PRACTICE OF THE ELECTRIC TELEGRAPH: A Handbook for Electricians and Operators. By FRANK L. POPE. Fourth edition, revised and enlarged. New York: D. Van Nostrand, 23 Murray street.

Although it is less than two years since this work was originally published, it has already become the standard treatise on American Telegraphy. For this reason we are glad to see that the enterprising publisher has brought out the present edition in a style much superior to its predecessors, and with corrections and additions which largely increase the practical value of the book. Even within the comparatively short time which has elapsed since this book was first written many new facts in regard to telegraphic practice, which had hitherto escaped notice, have been brought to light by the careful investigations of such men as Farmer and Brooks. This has been noticeably the case with regard to insulation and the arrangement of batteries.

Every year's experience of our best telegraphers is leading them to the inevitable conclusion that the fundamental defect of the whole system—in fact, the root of all the innumerable evils that telegraphs are heir to, is in defective insulation. A quarter of a century has been spent in unavailing efforts to palliate or avoid its effects, while the cause itself remained comparatively untouched. Self-adjusting relays, low resistance relays, enormously heavy conducting wires, and a half a hundred other devices have been successively heralded as the great specific remedy; but one by one the intelligent and thinking class of telegraphers are becoming convinced that all this is the merest empiricism and quackery. The disease itself must be rooted out. When our lines are once thoroughly and completely insulated it is an easy matter to dispose of every other difficulty that may arise. That these considerations have not escaped the notice of the author is evident from some changes which have been made in the original text, as well as the character of a portion of the new matter which has been added. Thus, on page 58 of the former editions, we read: "Experiments show that soot will destroy the surface insulation of even the best insulators, unless exposed to the cleansing action of the rain. Two years of experimenting have evidently impressed upon Mr. Pope's mind the undoubted fact that the "cleansing action of the rain" does not help the matter much, for in rain the outer surface of the insulator, though clean, is wet, and therefore a conductor, while the inside is both dirty and wet and also a conductor. He now says "even when exposed to

the cleansing action of the rain." An important difference, as will readily be perceived. Again, on page 63, referring to the English system of attaching earth wires to the poles, to cut off cross currents, the old editions remarked that "this practice might be adopted in this country with great advantage to the working of the line." The author has now arrived at the eminently sensible conclusion that, instead of adopting the practice referred to, "a much more economical and effective method of obtaining this result is that of improving the insulation."

Chapter IX. is composed entirely of new matter, relating to "Recent Improvements in Telegraphic Practice." Considerable information is given in regard to the newly invented "compound wire," and the "gravity battery," in its different forms. This, we think, is undoubtedly destined to be the universal telegraphic battery of the future, and the author, evidently foreseeing this, has given a concise but correct description of the battery, and directions for its management, which leave little to be desired in this respect. The Siemens Galvanometer, a very recent European invention for testing the lines, etc., is well described, and its principles illustrated. This instrument has met with a remarkable degree of favor in this country, some fifteen of them being already in use here with the most satisfactory results, although it is not a year since its first introduction. The Pope and Edison type printer, for private telegraph lines—another new and successful invention—is described and well illustrated. Nothing is said about the new automatic system which is exciting so much interest, probably because its details are not sufficiently complete to admit of a careful description.

A very valuable chapter on "the Equipment of Lines," a much neglected point in scientific telegraphy, has been added to the Appendix, and will excite much attention and perhaps some discussion among those interested. The recommendations contained therein certainly differ very widely in many cases from present practice. The portion relating to the arrangement of sounders and registers, in connection with their batteries, is excellent. The credit of the latter investigation was due originally to Mr. Brooks, and we are glad to find that Mr. Pope has embodied it in a permanent form. "The Working Capacity of Telegraph Lines" is a treatise on insulation in disguise, and a good one, too. There is food for much study and reflection in this article.

We are glad to see Ohm's method of geometrical projection, as applied to telegraphic circuits by Webb, embodied at length in a permanent form. It is curious, interesting, and valuable, and will be better appreciated a few years hence than it is now.

A great defect in the former editions of this work was the lack of an index. This has been supplied in the present one, and it is needless to say adds greatly to its value. These additions and improvements, as well as the handsome style in which the publisher has brought out the work, will no doubt insure it a continued and increased popularity among American telegraphers.—*The Telegrapher.*

THE YOUNG MECHANIC. A Book for Boys. Trubner & Co., London. For sale by Van Nostrand.

This little hand-book is a good manual of applied science for boys. The use of tools of all kinds is well described, as is also the precise manipulation to secure good work in lathe turning of different materials. The method of making miniature steam engines and other models is also fully given.

A LABORATORY TEXT-BOOK OF PRACTICAL CHEMISTRY; or Introduction to Qualitative Analysis. By W. G. VALENTINE. London, 1871. For sale by Van Nostrand.

THE STUDENT'S ELEMENTS OF GEOLOGY. By CHAS. LYELL. London, 1871. For sale by Van Nostrand.

No other writer on this science has made the subject so attractive to the general reader as this author. The illustrations in the present volume are abundant, there being 600 in all.

THE ESSENTIALS OF GEOMETRY. By J. R. MORELL. London: Griffith & Farran. For sale by Van Nostrand.

This little book is the result of a demand for some shorter route to the applications of geometry than is afforded by Euclid or his followers. To the teacher of mathematics the book will appear unsatisfactory. Such demonstrations as the book contains would hardly be considered beneficial to a student under mathematical training.

There is no doubt but that the French and German methods of teaching geometry are far better than ours. Euclid's methods, upon which our modern authors base their own systems, were spun out with reference to meeting all possible cavils rather than to instil the essential truths of the science.

Mr. Morrell's contains many good suggestions, but it will not succeed with instructors in its present form.

THE ANNUAL OF SCIENTIFIC DISCOVERY FOR 1871. Edited by JOHN TROWBRIDGE. S. B. Boston: Gould & Lincoln. For sale by Van Nostrand.

The bare announcement of the appearance of this book serves as a sufficient notice. All readers of science keep the series at hand for reference.

The present number is not behind its predecessors in the variety or scientific value of its articles.

The notes by the Editor form a good introduction, and present a fair summary of scientific invention and discovery during the year.

The articles are carefully selected from a wide range of scientific periodicals, and it may be safely assumed that no important additions to our scientific knowledge have escaped record. On the other hand, the Editor has excluded all claims to discovery whose genuineness is at all doubtful, although the opportunities for gathering such have been frequent during the last few months.

Everybody needs the Annual.

PRELIMINARY EXPERIMENTS ON THE MECHANICAL AND OTHER PROPERTIES OF STEEL MADE OR COLLECTED BY COMMITTEE OF CIVIL ENGINEERS. London: Adams Brothers.

This is a pamphlet containing tabulated results of 203 experiments on the properties of steel, made under the direction of Mr. Kirkaldy.

The results are of great interest to all who use steel.

The experiments are upon tempered and un-

tempered specimens, and upon a great variety of brands. The figures alone are given; no theory is discussed, and there are no more remarks than serve to elucidate the tables.

GUN CARRIAGE FOR HEAVY ORDNANCE. Invented and Patented by Capt. JOHN WALL WILSON, U. S. R. M. New York. 1870.

A small duodecimo in neat form, containing a large folding lithograph of a carriage, designed for a 100 lbs. Parrott gun. The descriptive text is supplemented by letters from savans and experts on the merits of the materials and in the construction, and also upon the success of the invention as a whole.

THE PRUSSIAN INFANTRY OF 1869. Translated from the German by Col. HENRY AIME OUVRY, C. B. London: Mitchell & Co. For sale by Van Nostrand.

This is a well printed pamphlet of 120 pages, containing a complete discussion of the theory of the Prussian infantry tactics.

MISCELLANEOUS.

THE PACIFIC SUBMARINE CABLE.—The Committee of the Chamber of Commerce charged with the subject of Telegraphs and Postal Affairs, of which Samuel B. Ruggles is chairman, reported on the 20th of December last the following resolution, which was adopted:

Resolved, That the Chamber of Commerce of the State of New York regard a well-regulated system of telegraph, by sea and by land, as a matter of primary importance to the interests of this country and of the world, and respectfully ask that Congress may pass, at an early day, such laws as will, without creating any monopoly, facilitate the laying of a submarine cable across the Pacific Ocean, from the western coast of America to the eastern coast of Asia, thereby completing, with the lines now in operation, and with those soon to be laid, telegraphic communication around the world.

The committee now report upon (1.) The locality and length of the telegraphic lines already established, and of those which are still needed to complete a communication around the globe. (2.) The influence of the work, when completed, upon the commerce of the world, and especially the commerce on the Pacific and the Indian Oceans.

LOCALITY.—The telegraph line, when completed, will necessarily embrace the 360 deg. of longitude encompassing the globe. This great circle is divided into two segments, unequal in length, but each containing a continent and an ocean. The Western embraces the Western Continent and the Atlantic Ocean, extending from San Francisco, in California, to Valentia, in Ireland, over 112 deg. of longitude; while the Eastern embraces the Eastern Continent and the Pacific Ocean, extending from Valentia to Shanghai, in China, over 132 deg. of longitude, and thence across the Pacific Ocean, over the remaining 116 deg., thus completing the entire circle of 360 deg. Of these two segments of this great terraqueous line, the Western, from San Francisco to Valentia, has been finished largely, if not mainly, by the energies of the citizens of the United States. Of the Eastern segment, the portion crossing the Eastern Continent is now nearly completed. Two continuous lines extend eastwardly from Valentia, one inclining to the north through the United Kingdom, Germany, European and Asiatic Russia, to the present temporary terminus at Kiachta, an important Russian entrepot in Eastern Siberia, near the Chinese frontier, in north latitude 51 deg.; while the other pursues a southeasterly course through France, Austria, Turkey, Persia, and other Asiatic countries, to Bombay, in Hindostan, and thence by way of Ceylon to Singapore, only 1 deg. 30 min. north of the equator. Kiachta is 116 deg. and Singapore 113 deg. east from Valentia. The land line through Turkey and Persia being liable to occasional interruption in regions only partially civilized, a submarine line has also been laid from Italy through the Mediterranean Sea, the Red Sea, and the Arabian Sea to Bombay.

By the lines above described commercial and other messages are now regularly telegraphed, without interruption, from London to Kiachta and Singapore. Through the commercial house of A. A. Low & Brothers, of New York, largely engaged in the trade of China and Japan, the committee have ascertained that the extension of the submarine cable from Singapore to Hong Kong about 1,400 miles, and thence to Shanghai, about 1,000 miles, is in active progress. By a letter recently received by Mr. Cyrus W. Field, and exhibited to the committee, they are informed that the line from Singapore to Hong Kong will be laid by the first of May, and be in actual operation by the first of June next. An Australian line will be completed to Singapore within the present year.

Two telegraphic lines under the Pacific have been suggested to the committee:

One commencing at San Francisco, in latitude 37 deg., and deflecting southwardly to the Sandwich Islands, in latitude 20 deg., and thence inclining northwardly, by way of the Midway Islands, in latitude 27 deg. north, to Yokohama, in Japan, in latitude 35 deg. north, and thence southeasterly to Shanghai, in latitude 32 deg. Its length will be 5,430 nautical miles from San Francisco to Yokohama, and from Yokohama to Shanghai 1,035 miles—in all 6,515 nautical miles. The other and more northern line will extend from San Francisco along the coasts of British Columbia, Alaska, and the Aleutian Islands, to the eastern coast of Japan, and thence to Shanghai.

The report considers quite at length the influence of a Pacific cable on the foreign commerce of the world. The total foreign commerce of the European and American nations, in which is included all their commerce with the Asiatic countries, consists as follows: Commerce of the European nations, $7,203,390,415; that of American nations, $1,640,822,697; total, $8,844,213,112. The aggregate value of the commodities actually moved is one-tenth of the $8,844,213,112, or $884,421, 311, and one-half of the residue, $7,959,791,801, being $3,979,895,901; the total is $1,864,317,212. The commerce of the Pacific and Indian Oceans is next considered. From the detailed statements in the table the following general facts will appear:

(1.) Of the commerce of Europe and America with Asia, on the Pacific and Indian Oceans, being, in 1868, $735,141,550; the three maritime powers, the United Kingdom, France, and the United States, had $672,103,550, and (2) their commerce on those oceans in 1854 was $330,079,742, showing an increase in the 14 years of $342,-

023,808, being 103 per cent., or 7.35 per cent. yearly. (3.) From the proportion of exports to imports shown by the tables of the three nations, we may safely estimate that of the total commerce of $735,141,550 the exports to the Asiatic countries did not exceed $300,000,000, so that the imports from these countries were at least $435,141,550. (4.) Of the last named amount, Australia and New Zealand furnished $62,942,240, and the more tropical countries of Asia the remaining $372,199,310. It is this last portion which imparts to the commerce on the Pacific and Indian Oceans its peculiar interest.

The conclusions to which all these facts lead the committee are in brief these: It surely requires no great stretch of imagination or credulity to believe that a commerce so beneficent and civilizing, in a world like ours filling up with people so rapidly, is destined to large and speedy increase, especially if wisely aided by our National Government. It is not for the clear-headed, far-sighted merchants of the United States to close their eyes upon the fact that, in the providential march of events, a field so vast is just opening to their well-directed energy. The products of the globe will take the shortest and cheapest road to market. San Francisco will be the entrepot for a vast part of the Oriental trade, and should therefore be speedily put in telegraphic communication with the continent of Asia.

Improved Safety Lamp.—A miner's safety lamp, possessing several novel features, and designed for the burning of paraffine oil, has just been invented by Mr. William Simpson, of Battersea; and from the report made upon it after practically testing it in a mine, it is probable that with some trifling modifications in detail, it will thoroughly answer the purposes for which it is intended. The oil-chamber is of annular form, the passage through the centre being carefully covered at the bottom with wire-gauze. A bridge across the upper end of the opening connects the oil-vessel with an ordinary flat-wick paraffine burner, provided, however, with an automatic extinguisher, to prevent the exposure of the flame by the opening of the lamp. This extinguisher is extremely simple, consisting of two small plates, which, whilst acted upon by the spring provided for that purpose, cover the wick and wick-tube; but whilst the lamp is in use this spring is held back by a catch in such a manner as to be once released upon any attempt being made to unscrew the lamp top. The vastly superior light and greatly increased economy of paraffine oil, as compared with candles, is so well known that it need not be referred to; and if Mr. Simpson can succeed in introducing his lamp into collieries, colliers will have no excuse for opening their lamps to increase their light. The new lamp, as at present constructed, is 18 in. high, and 4½ in. diameter, and is provided with a tripod 2 ft. high in which the lamp is suspended, in order to prevent the possibility of it assuming anything but a vertical position when it stood upon the floor of the mine; future specimens, however, will be made 4 in. shorter, so as to approach more nearly the size of the lamps at present in use. The price of the lamp and tripod complete will not exceed 8s. 6d., which is rather under than above the price of a good Stephenson, so that expense will be no bar to its adoption.

The lamp has been thoroughly tested by Mr. J. Morton, mining manager to Young's Paraffine Light Company, Glasgow, and his report upon it is decidedly favorable, although he suggests several modifications, which he considers would improve the value of the lamp, which he states he found to have several advantages and also several serious objections. He first examined a working-place with a Davy lamp, and found it to contain fire-damp along the roof, 1 ft. deep, about 6 ft. in length, and 4 ft. in breadth. He afterwards took the paraffine lamp, and could not by any means detect fire-damp, on account of the extra height from the flame to the top of the lamp, it coming in contact with the roof, before the flame was allowed to come in contact with the fire-damp. He then put the two lamps alongside of each other, and found it the same as before, viz.:—Fire-damp in the Davy lamp, and no appearance in the paraffine lamp. He afterwards laid aside the Davy lamp, and raising the paraffine lamp to the roof, he slowly waved his hand, and brought the fire-damp down upon the flame, when a slight explosion took place inside the lamp, exactly similar to what happens in the Davy lamp under the same circumstances. The outside gauze after this experiment was perfectly cool. He next tried it in a strong current of air coming direct from a small pair of fanners, and found it to have no visible effect on the flame, whereas a naked light put alongside of it was completely extinguished, thus showing to what advantage it could be carried against a strong current of air with perfect safety, although the air might be mixed with a large proportion of fire-damp. He is, therefore, of opinion that it is a first-class lamp, in fact, superior to anything that he has seen, for workmen who might be required to work in a place, containing a small proportion of fire-damp, as owing to its superior light they could perform their work with nearly as much freedom as with a naked light, and with comparatively perfect safety, and would be of invaluable use in any large mine, where nothing but safety-lamps were used by the workmen; but it is not at all suitable for a fireman examining the working faces of a mine, owing to its deficiency in detecting fire-damp in the small cavities and fissures of the roof, and could not be used for that purpose. If there was any possible way of conducting the flame on a white heat to the top of the funnel so that it would come in contact with the fire-damp at that point, it would obviate the most serious objection, and altogether change the qualities of the lamp—in fact, would make it superior to any safety-lamp at present extant.

Of the great illuminating power of Mr. Simpson's lamp there can be no question; and as he appears to have already succeeded in removing the defects, without lessening its advantages, it may be anticipated that more will soon be heard of it.—*Mining Journal.*

Russia and China.—Indian papers state that a Russian line of steamers is to be put on the Odessa and China line, *via* the Suez Canal, for the transport of tea and other merchandise to and from Southern Russia.

In Belgium furnace slag is now utilized by allowing it to run off into moulds along the sides of the furnace, in which it assumes the form of rectangular blocks of any size. When cold, the mass forms a compact, homogeneous slag, very much resembling porphyry, and is well adapted for building and engineering purposes.

CAPTAIN ERICSSON'S DYNAMIC REGISTER.

PAGE 561.

FIG. 1.

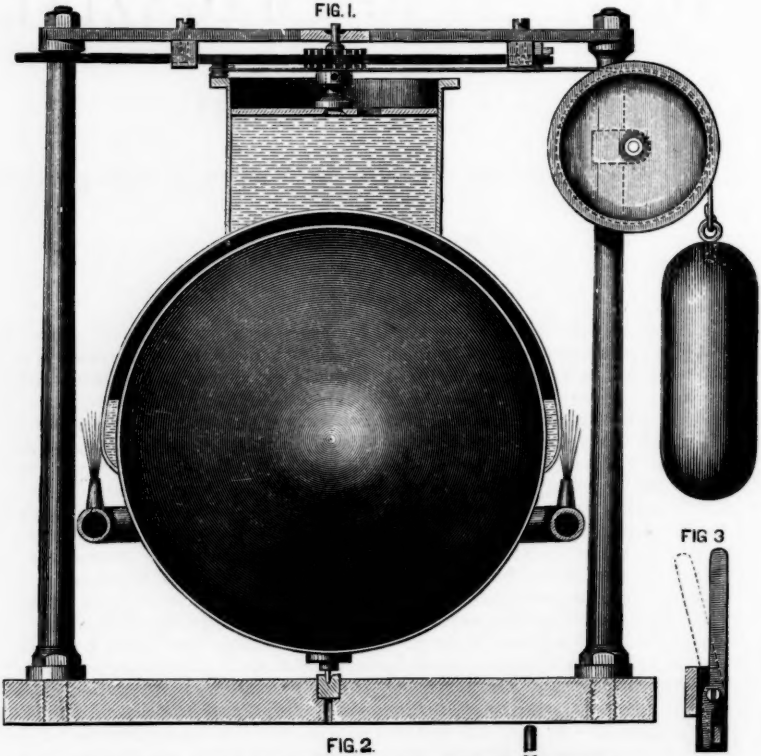


FIG 3

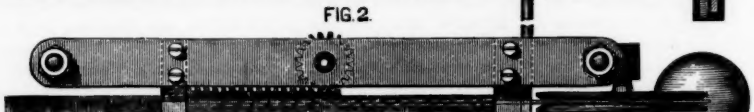



FIG. 2.